4.16 HUMAN HEALTH AND SAFETY

This section describes the responsibilities of existing LLNL programs for assuring that their respective activities are executed in a manner protective of the general public, worker safety and health, and the environment.

Environment, Safety, and Health Functions and Responsibilities

It is the policy of NNSA and LLNL to operate in a manner that protects the health and safety of employees and the public, preserves the quality of the environment, and prevents property damage. ES&H is to be a priority consideration in the planning and execution of all work activities at LLNL. It is also the policy of LLNL to comply with applicable ES&H laws, regulations, and requirements; and with directives promulgated by DOE regarding occupational safety and health, as adopted in the LLNL Work Smart Standards. LLNL encourages public participation on matters of importance to the community related to environmental protection and health and safety. Public participation is encouraged through the initiation of communications and solicitation of public input to the decision-making process on matters of significant public interest and by providing access to information on LLNL ES&H activities (LLNL 1998d).

LLNL has implemented an Integrated Safety Management System (ISMS), in accordance with DOE G 450.4-1A to "…systematically integrate safety into management and work practices at all levels so that missions are accomplished while protecting the public, the worker, and the environment." The ISMS is a systematic approach to defining the scope of work, identifying, planning, and performing work that provides for early identification of hazards and associated control measures for hazardous mitigation or elimination. The ISMS process also forms the basis for work authorization and provides for both internal and external assessment through a continuous feedback and improvement loop for identifying both shortcomings and successes for incorporation into subsequent activities (LLNL 2003k). ISMS is discussed in detail in Appendix C.

The LLNL Director is responsible for the overall implementation and oversight of ES&H responsibilities and is assisted by the Senior Management Council and the ES&H Working Group. The Senior Management Council, composed of the Director (Chair), the Deputy Directors, and all Associate Directors, advises the LLNL Director on policies and oversees the effectiveness of activities and programs to implement those policies. The Senior Management Council is responsible for:

- Reviewing LLNL policies and recommending changes to the Director
- Ensuring the implementation of those policies and reviewing the effectiveness of their implementation
- Discussing accidents, incidents, audits, and reviews at LLNL and other NNSA contractor facilities to identify lessons learned and ensuring that those lessons are incorporated into LLNL operations
- Establishing and overseeing working groups and committees as appropriate
- Providing a forum to receive input from LLNL employees and ensuring that they are adequately informed

- Reviewing proposed exemptions to standards and regulations
- Reviewing and resolving outstanding institutional issues

The ES&H Working Group supports the Deputy Director for Operations and the Senior Management Council. Its broad membership and close association with the Deputy Director for Operations and Senior Management Council provides a key mechanism for LLNL-wide reviews of proposed ES&H policies and issues and for the development of effective ES&H guidance. The ES&H Working Group consists of assurance managers from each directorate and the heads of the ES&H functional organizations. ES&H Working Group responsibilities include the following:

- Responding to requests for reviews and studies by the Deputy Director for Operations
- Reviewing and developing LLNL implementation plans to meet Federal, state, and DOE requirements
- Addressing ES&H and quality assurance issues raised by the programs and preparing recommended actions for consideration by the Deputy Director for Operations and Senior Management Council
- Reviewing generic or institutional ES&H and quality assurance issues, and bringing those issues to the attention of the Deputy Director for Operations for policy development or change

The EPD assists LLNL managers to ensure that LLNL operations comply with applicable laws and regulations and that environmental impacts from LLNL operations are mitigated to the maximum extent possible. The EPD's key missions are as follows (LLNL 1996b):

- Assist LLNL programs in developing environmentally sound practices in their day-to-day tasks by: (1) conducting environmental evaluations and addressing requirements under NEPA, CEQA, and related Federal and state requirements; (2) identifying and developing methods to monitor, prevent, reduce, and clean up air emissions, wastewater discharges, and hazardous wastes; and (3) obtaining the permits or exemptions for air, water, and hazardous waste activities
- Ensure environmental compliance through environmental monitoring, risk assessment, and analysis for LLNL sites by evaluating the impact of ongoing LLNL operations on the surrounding environment by sample collection, analysis, data reduction, and other simulation modeling methods for water and air
- Develop and conduct cost-effective restoration and remediation
- Design and apply appropriate, cost-effective treatment technologies to manage hazardous and nonhazardous waste streams
- Develop and implement waste minimization and pollution abatement strategies
- Coordinate LLNL-wide D&D activities

The EPD is divided into three operating divisions, each with specific responsibilities (for more details, see Appendix C, Environment, Safety, and Health): RHWM Division, ERD, and Operations and Regulatory Affairs Division. The RHWM Division develops and improves methods to ensure that wastes from LLNL operations have minimal environmental impacts. They operate LLNL's hazardous, radioactive, and mixed waste management systems. The ERD investigates and cleans up soil and groundwater contaminated by past activities of LLNL and its predecessors at the Livermore Site and Site 300. The Operations and Regulatory Affairs Division is the focal point for interactions with Federal, state, and local environmental regulatory agencies. It offers technical guidance and expertise on regulatory requirements and related compliance options, permitting issues, and monitoring techniques and technologies, as well as providing 24-hour emergency response for environmental incidents.

The Hazards Control Department, through its five ES&H teams, works with LLNL programs to minimize the risks presented by research and support activities. The hazards encountered include all biological, physical, and radiological agents from normal operating conditions to emergencies. The Hazards Control Department also provides safety analysis, and emergency preparedness and response training services and operates state-of-the-art analytical laboratories. The Hazards Control Department's primary responsibilities include monitoring operations to provide management with the information needed to maintain an acceptable-risk work environment, provide guidance in formulating LLNL's health and safety policies, directives, and standards; conduct facility design reviews; and specify any protective equipment that might be required by employees to perform their work assignments safely. The Hazards Control Department assists the programs in the implementation of the LLNL ISMS. In the ISMS context, the term safety is synonymous with the LLNL term ES&H. It encompasses protection of employees, the public, and the environment. The overall responsibility for implementing this belongs to line management.

The Health Services Department provides occupational health services for LLNL. This department works collaboratively with the Hazards Control Department and EPD. The Health Services Department Head serves the role of Chief Medical Officer at LLNL and provides input for health-related decisions made by LLNL management. The Health Services Department staff provides clinical services and employee assistance and offers the following occupational health services:

- Treatment for occupational and minor non-occupational injuries and illness
- Emergency care, stabilization, and transfer to local emergency room if necessary
- Return-to-work assistance after illness or injury
- Multidisciplinary work site inspections regarding health hazards and environmental conditions, medical surveillance, and qualification and fitness for duty examinations
- Educational programs designed to address health concerns in the workplace
- Health promotion services
- Physical therapy for occupational injuries or illness
- Decontamination and treatment for chemical or radiological exposures
- Employee assistance services

The Health Services Department also implements prevention programs for occupational illnesses and injuries, such as monitoring worker exposure data with the Hazards Control Department and preventing Valley Fever (coccidioidomycosis) at Site 300. The programs mentioned above are further discussed in Appendix C.

4.16.1 Occupational Safety

4.16.1.1 *Regulatory Setting*

The Work Smart Standards, which includes Federal and state regulatory requirements, is a set of codes, standards, and regulations adopted between LLNL and NNSA (LLNL 1998e). Information on the contractual adoption of Work Smart Standards, as well as standards maintenance, flow down of requirements, and change control process, is included in Appendix C, Section C.2.2, of this LLNL SWEIS.

4.16.1.2 *Lawrence Livermore National Laboratory Occupational Safety*

Each employee at LLNL, from Director to laboratory worker, is required to know and understand the ES&H requirements of his or her assignment, the potential hazards in the work area, and the controls necessary for working safely. He or she must participate in all required ES&H training and health monitoring programs. All work assignments must be performed in full compliance with applicable ES&H requirements as published in LLNL manuals and guidelines and established in safety procedures. All employees are responsible for working in a manner that produces high quality results, preserves environmental quality, and protects the health and safety of workers and members of the public. Program implementation is a line management responsibility, with primary oversight of program implementation resting with the Hazards Control Department and Health Services Department (LLNL 1996b). These organizations are described briefly above and further discussed in Appendix C. An organization chart is also provided in Appendix C, Section C.2.2, of this LLNL SW/SPEIS.

The Assurance Review Office is LLNL's institutional-level ES&H oversight organization reporting to the Deputy Director for Operations. The Assurance Review Office mission is to assist the Laboratory's Deputy Director for Operations in discharging his ES&H and related quality assurance responsibilities by providing independent, institutional-level oversight of LLNL's ES&H systems and nuclear facility safety. The Assurance Review Office also serves as a point of contact and coordinating agent for major DOE and University of California ES&H reviews, assessments, and audits. The Assurance Review Office's role is to conduct independent reviews of LLNL's ES&H and related quality assurance systems, including nuclear facility operations and the directorate self-assessment processes.

The Assurance Review Office evaluates the adequacy of existing ES&H systems relative to LLNL's ES&H policies and procedures and applicable ES&H laws, regulations, and directives. The results of the Assurance Review Office's reviews are communicated to the Deputy Director for Operations, directorates, nuclear facility management, and ES&H support organizations with the intent of facilitating improvements in LLNL's ES&H, nuclear facility safety, self-assessment, and institutional oversight programs. The Assurance Review Office is responsible for independently assessing conformance with LLNL's nuclear safety implementation plans prepared in accordance with the *Price-Anderson Amendments Act* rules. The Assurance Review Office maintains the institutional ES&H deficiency tracking system (DefTrack) to monitor actions taken in response to its evaluations and assessments conducted by outside agencies and the directorates. The Assurance Review Office is precluded from assuming any line or programmatic responsibilities to ensure functional independence and appropriate segregation of responsibility (ARO 2003).

The LLNL ISMS addresses the identification of workplace hazards, control measures, safe work practices, and feedback and continuous improvement functions necessary to perform work safely at LLNL. This program articulates the institutional requirements for all LLNL operations, whether at the Livermore Site, Site 300, or Nevada Test Site, or at any other sites where LLNL personnel and contractors are working. The LLNL ISMS was implemented in 1998 with the updating of existing safety manuals and organization into a formal structure within the ISMS Plan. Additionally, in 1997, LLNL and the DOE Oakland, California office initiated the selection of Work Smart Standards to protect workers, the public, and the environment. These standards are the basis for selecting hazard controls and other processes at LLNL (LLNL 2003k).

Special Illness Prevention Program

Site 300 workers and visitors face the potential of contracting coccidioidomycosis, a respiratory disease commonly known as Valley Fever, caused by the fungus *Coccidioides immitis*. The disease is common in warm, dry alkaline areas including the entire San Joaquin Valley. Coccidioidomycosis is acquired from inhalation of the spores (arthroconidia). Once in the lungs, the arthroconidia transform into spherical cells called “spherules.” An acute respiratory infection occurs 7 to 21 days after exposure and typically resolves rapidly. However, the infection may alternatively result in a chronic pulmonary condition or disseminate to the meninges, bones, joints, and subcutaneous and cutaneous tissues. About 25 percent of the patients with disseminated disease have meningitis (DoctorFungus 2002). The Health Services Department tests each employee or prospective employee for Valley Fever immunity before assignment to Site 300, subject to the availability of the antigen (see Appendix C). The test is currently unavailable and may remain unavailable beyond 2003. Based on the test results and physical factors (e.g., greater susceptibility or being pregnant), employees are counseled regarding increased risk, and the Health Services Department recommends if working at Site 300 is appropriate. An employee can work at Site 300 despite a contrary recommendation if an informed consent form is signed (LLNL 2000i).

Other Exposures and Potential Hazards

Exposures to Hazardous Materials

LLNL is an R&D facility in which a large variety of hazardous materials are used. LLNL operations represent a potential for exposure of some workers to hazardous materials (such as solvents, metals, and carcinogens). Typically operations are controlled so that those workers may be exposed to very low levels of a wide variety of chemicals that are below a threshold of concern throughout the duration of their research. A summary of radioactive materials and chemicals to which workers may be exposed can be found in Appendix B, Waste Management. Radioactive and hazardous wastes are also discussed in Appendix B. LLNL evaluates operations and prevents employee exposures to chemical hazards. Hazards Control tracks measured exposures to hazardous chemicals in an electronic database (LLNL 2002bk).

Workers are provided with information and training on identified hazards to protect them from exposure. LLNL has several programs and procedures in place to provide direction for monitoring, handling, storing, and using these materials. These programs and safety procedures include the Hazard Communication Program, Chemical Hygiene Program, Respiratory Protection Program, and written safety procedures for handling and use of carcinogens and biohazard materials. Work activities are periodically monitored with measurements performed at personal breathing zones and general work areas. ES&H monitoring records indicate that personnel exposure to hazardous materials is maintained well below established regulatory requirements and exposure guidelines. Additional information regarding worker exposure to toxic materials is found in Appendix C (LLNL 2000i).

Biohazards

Biological operations at LLNL include using and safely handling biohazardous materials, agents, or their components (e.g., microbial agents, bloodborne pathogens, recombinant deoxyribonucleic acid [DNA], and human or primate cell cultures), and research proposals and activities concerning animal or human subjects. Biological materials can cause illness and infection. Examples of potential sources of exposure to biological hazards are as follows:

- Human fluids, secretions, or feces
- Class II and III etiologic agents
- Infectious agents from animal infestation or droppings
- Biological toxins
- Human cell and tissue culture systems
- Research involving animals
- Research involving allergens of biological origin (e.g., certain plants and animal products, danders, urine, and some enzymes)
- Laundry soiled with blood or other potentially infectious materials
- Contaminated sharps
- Unfixed human tissues or organs

Personnel exposure to biological hazards is minimized using administrative controls, engineered controls, and personal protective equipment. By analyzing the hazards for each specific operation, LLNL personnel develop and implement the appropriate controls to protect themselves, the community, and the environment from potential exposure (LLNL 2000i).

Carcinogens

Carcinogens are only used in LLNL operations when it is not possible to use a noncarcinogenic material. Any use of carcinogens requires stringent controls to be in place to prevent exposures to workers, the public, and the environment. Examples of operations where carcinogenic materials may be encountered include:

- Brazing with cadmium-containing alloys or grinding of cadmium-coated work pieces
- Work that generates or involves contact with soots and tars
- Use of mineral oil products that may contain polyaromatic hydrocarbons
- Electric arc discharge machining
- Discharging of gas propellants in a vacuum
- Handling refractory ceramic fibers
- Welding stainless steels (due to the formation of hexavalent chromium compounds and nickel oxide)
- Chromium plating and other operations that disperse hexavalent chromium compounds or irritatingly strong concentrations of sulfuric acid into the air
- Generating hardwood dust, including carpentry and cabinet-making activities
- Spraying hexavalent chromium compounds including, but not limited to, primers, paints, and sealants containing barium, calcium, sodium, strontium, or zinc chromate
- Handling inorganic arsenic compounds and arsenic metal, including gallium arsenide, in a manner that can result in exposure to arsenic
- Handling animals in research activities involving carcinogens
- Using or synthesizing of carcinogens in laser chemistry or biochemistry laboratories
- Using asbestos, beryllium, laser dyes, or lead and lead compounds

At LLNL, chemical carcinogens are used by employees only when required by a specific research project. The use of chemical carcinogens is addressed in the Chemical Hygiene Plan and the ES&H Manual requirements (LLNL 2000i). The program addresses control and storage of chemicals, preparation of work plans, worker safety, personnel protective measures, engineering controls, and waste management.

As addressed previously, worker exposures to certain hazardous materials are monitored by industrial hygiene staff and tracked using an occupational exposure database. Likewise, personnel may be monitored for certain chemical agents by way of routine medical examinations performed by the Health Services Department.

The use, synthesis, and storage of carcinogens must be evaluated by an industrial hygienist. Depending on the nature of the chemical use, the quantity of material involved, and the control measures engaged, procedural guidance might be required for the performance of work using carcinogens.

The purchase and receipt of chemical carcinogens is primarily controlled through procurement administrative controls. Authorization for the purchase of carcinogens requires either a current Operation Safety Plan or the approval of the area industrial hygienist. Occupational Safety and Health Administration (OSHA)-regulated carcinogens may only be purchased with approval of the Hazards Control Department.

All employees who work with carcinogens must receive sufficient information and training so that they may work safely and understand the relative significance of the potential hazard they may encounter (LLNL 2000i).

Beryllium Disease Prevention Program

Beryllium metal, alloys, and compounds are widely used at LLNL and other DOE facilities because of the materials' nuclear properties as moderators (i.e., reflectors) of neutrons. Favorable mechanical properties have also resulted in beryllium's widespread use in the aerospace industry. The addition of 2 percent or less beryllium to copper forms an alloy with high strength and hardness, properties that have made the alloy useful in electronics, automotive, defense, and aerospace industries worldwide. Beryllium oxide (also known as beryllia) can be formed into beryllia ceramics, which have an exceptional combination of high thermal conductivity, electrical resistivity, and dielectric properties. Beryllium ceramics are used widely in electronics, laser, automotive, and defense applications (LLNL 2000i).

Although solid beryllium poses no health hazard, inhaling beryllium particulates (such as dust, mists, or welding fumes) can produce acute or chronic lung disease. Skin irritation may result from direct contact with soluble beryllium compounds, and healing is impaired in beryllium-contaminated wounds. Health effects from beryllium are caused by the body’s immune system response to inhaled dust or fumes containing beryllium metal, alloys, or compounds. This immune system response to beryllium is similar to an allergic reaction and may evolve over many years, even decades. Early evidence of this reaction may be detected by a blood test; i.e., the beryllium lymphocyte proliferation test, before there is evidence of damage to the lungs. Positive test results indicate beryllium sensitization. Sensitization is not a disease. There is no impairment from or symptoms of, sensitization itself.

The body’s reaction may continue to progress and cause damage to the lungs. Chronic beryllium disease is said to exist when there is evidence of harmful effects to the lungs; i.e., when healthy lung; tissue becomes damaged and changes from functioning lung tissue to fibrotic tissue. Damage to the lungs may be detected early by biopsy before there are symptoms (such as shortness of breath. Damage such as fibrosis may progress to the point that symptoms are severe enough to disable or cause death.

LLNL's Beryllium Disease Prevention Program addresses a new DOE effort designed to reduce the number of workers exposed to beryllium, minimize the levels of beryllium exposure, and ensure early detection of beryllium-related disease. LLNL's control program consists of:

- Workplace evaluations and establishment of controls
- Training
- Medical surveillance

The Beryllium Disease Prevention Program is part of long-standing beryllium control efforts at LLNL that predate any Federal mandates. These controls, plus a high level of awareness of the hazards of beryllium among scientists, engineers, technicians, and other staff who work in areas where beryllium is used, have resulted in a low beryllium disease rate at LLNL.

Workplace exposure questionnaires and the availability of a new blood test are two major enhancements to LLNL's Beryllium Disease Prevention Program. The blood test, called the lymphocyte proliferation test, detects sensitivity to beryllium. Employees who become sensitized are more likely to develop beryllium lung disease.

For most people, chronic beryllium disease results from significant exposures to beryllium from activities such as machining or working with powder or dust. A small percentage of individuals can develop chronic beryllium disease from a very low level of dust. Chronic beryllium disease, a poorly understood lung disease, may take years or even decades to develop, and the primary symptom is shortness of breath on exertion. The lymphocyte proliferation test can identify individuals who have a greater risk of getting chronic beryllium disease, because their bodies have developed a response to the metal (a positive sensitivity).

As part of the hazard assessment process, everyone involved in beryllium work is evaluated to determine if DOE's criteria for classification as a "beryllium worker" is met. This determination is made by both program management and the ES&H team industrial hygienist. ES&H Manual Document 14.4, "Implementation of Chronic Beryllium Prevention Program Requirements" identifies the requirements and provides guidance for making the determination (LLNL 2000i). Part of the process is the "Beryllium Occupational History Questionnaire." This is filled out by everyone involved in beryllium work. A copy is maintained by the Hazards Control Department and Chemical and Biological Safety Section and a copy is forwarded to the Health Services Department and placed in the employee's medical record. The questionnaire provides important information to both the Health Services Department and the Hazards Control Department about current and past exposure potential.

If an employee has a confirmed positive (meaning two consecutive positive lymphocyte proliferation tests), additional medical testing (e.g., bronchoscopy, etc.) will be recommended to determine if the employee actually has beryllium disease. Positive sensitivity does not necessarily mean that disease is present. Health Services Department clinicians provide health counseling, which include a recommendation to eliminate any work with beryllium. All lymphocyte proliferation test results are managed in a medically confidential manner. Training on beryllium hazards is available from the Hazards Control Department.

LLNL's Health Services Department offers medical screening and surveillance to beryllium-associated workers. These are workers in any one of the following categories:

- Beryllium workers
- A worker whose work history shows he or she may have been exposed to airborne beryllium
- A current worker who shows signs or symptoms of beryllium exposure
- A current worker who is receiving medical removal protection benefits

Although the Beryllium Disease Prevention Program is open only to current LLNL employees, DOE has developed medical screening options for former employees who may have had beryllium exposure. The *Energy Employees Occupational Illness Compensation Program Act* of 2000 as amended concerns workers involved in various ways with the nation's atomic weapons program. Part A of the Act provides Federal monetary and medical benefits to workers having radiation-induced cancer, beryllium illness, or silicosis. Eligible workers include DOE employees, DOE contractor employees, as well as workers at an "atomic weapons employer facility" in the case of radiation-induced cancer and illness.

LLNL analyzes Site 300 soils for beryllium. Soils at the Livermore Site were analyzed for beryllium from 1991 to 1994. However, analysis for beryllium was discontinued at the Livermore Site in 1995, because it was never measured above background values (LLNL 2001v).

Physical Hazards

LLNL employees could also be exposed to physical hazards such as non-ionizing radiation, to include static magnetic and electric fields, extremely low frequency fields, radio frequency fields, and microwaves, noise, electric shock, tripping hazards, and lasers. The ES&H Manual provides procedural guidance for mitigating these types of hazards, and occurrences of such hazards are monitored by the Hazards Control Department.

Occupational Injuries

LLNL records occupational injuries pursuant to DOE orders that use OSHA criteria. Total recordable case rates for injury and illness incidence at LLNL varied from an annual average of 6.9 to 3.0 per 200,000 hours worked from 1996 to 2002. During this time, total lost and restricted day case rates ranged from 2.8 to 0.9 per 200,000 hours worked (LLNL 2002ck, LLNL 2003u). The total recordable case rate for LLNL workers is more than for DOE and its contractors at other facilities, which varied from 3.5 to 2.4 per 200,000 hours worked. During this time, total lost day case rates for DOE varied from 1.7 to 0.9 per 200,000 hours worked. No fatalities occurred at LLNL between 1996 and 2002 (DOE 2002f).

4.16.2 Human Health and Worker Safety (Radiological Effects)

The environment potentially affected by radiological site releases includes air, water, and soil. These transport pathways (the environmental medium through which a contaminant moves) require an associated exposure pathway (e.g., inhaling air, drinking water, or dermal contact with soil) to affect human health. The specific resource sections in this LLNL SW/SPEIS (e.g., Air Quality and Water) describe the existing conditions of the environmental media.

4.16.2.1 *Public Health*

A radiation dose is calculated to determine the health impact from exposure to radiation. The dose is a function of the exposure pathway (external, inhalation, or ingestion) and the type and quantity of radionuclide involved. The transport pathway (air, water, soil) concentrations, uptake parameters, usage rates, exposure duration, and radionuclide-specific dose factors determine the dose. The dose is always presented in this document (unless otherwise noted) as the Committed Effective Dose Equivalent, which weights the impacts on particular organs so that the dose from radionuclides that affect different organs can be compared on a similar (effect on whole body) risk basis. Health impacts (cancer fatalities) are calculated from the risk factor of 0.0006 fatal cancers to the general population expected per person-rem effective dose equivalent (Lawrence 2002).

The levels of exposure from the small quantities of radiation released from LLNL can be put in perspective by considering the doses received in the U.S. from exposure to natural and man-made background radiation. Table 4.16.2.1–1 compares the dose received from background and from a recent year of LLNL operations, 1999. The year 1999 is used because the doses received from LLNL operations were generally the greatest of the 5-year period 1998 through 2002. The air transport pathway results in almost all of the doses to the public from LLNL, either directly or through deposition and subsequent ingestion.

The risk of the hypothetical site-wide MEI contracting a fatal cancer from exposure to 1999 releases is 7.2×10^{-8} and 2.1×10^{-8} from the Livermore Site and Site 300, respectively. These same releases are unlikely (0.008 cancers calculated) to increase the number of LCFs in the population surrounding LLNL above those that occur naturally. The average annual cancer death rate nationally is 171.4 per 100,000 population; for California the rate is 161.7 per 100,000 population (Ries et al. 2002). Thus, approximately 11,000 fatal cancer deaths per year would be expected to naturally occur in the population of approximately 7 million people within 50 miles of LLNL.

TABLE 4.16.2.1–1.—*Comparison of Radiation Dose Received from Background and Lawrence Livermore National Laboratory Operations for 1999*

Location/Source	Individual Dose to Site-wide MEI[a] (millirem)	Population Dose[a] (person-rem)
Livermore Site		
Atmospheric emissions	0.12	1.7
Site 300		
Atmospheric emissions	0.035	11
Other (background)[b]		
Natural background		
Cosmic radiation	30	190,000
Terrestrial radiation	30	190,000
Food consumption	40	250,000
Radon	200	1,250,000
Man-made background		
Medical (diagnostic)	53	330,000
Weapons test fallout	1.1	6,800
Nuclear fuel cycle	0.4	2,500

Sources: LLNL 2000g, LLNL 2002cc.
[a] See Section 4.10, Air Quality, for description of site-wide maximally exposed individual (MEI) and population dose.
[b] Average over the U.S. population; values vary with location.

4.16.2.2 *Worker Health and Safety*

The LLNL Hazards Control Department provides training, planning, and documentation support to site programs to minimize potential risks to workers and the environment. The department implements the ES&H Manual that specifies health and safety management, controls, and procedures in the workplace (LLNL 2000i). The manual requires that all individuals employed at LLNL wear a dosimetry badge; visitors are also required to wear such a badge if they enter a radiation area. A dosimetry badge measures external exposure to radiation.

Internal exposure is typically monitored by bioassays (e.g., urinalysis, whole-body scans, lung counts). Routine bioassays are done on workers who, under typical conditions, are likely to receive a dose from an occupational exposure of 0.1 rem or more in one year. Others who could be assayed include occupationally exposed minors, members of the public, and pregnant workers who are likely to receive internal doses of at least 0.05 rem (or, in the case of pregnant workers, an equivalent dose to the embryo/fetus).

The applicable regulatory standard for radiological workers (those given unescorted access to radiation areas) is 5 rem per year (internal + external) (10 CFR Part 835). Table 4.16.2.2–1 lists the distribution of annual radiation doses (external + internal) received by LLNL workers for the recent 5-year period of 1998 through 2002.

TABLE 4.16.2.2–1.—*Distribution of Worker Doses for 1998 through 2002*

Dose Range (rem)	Number of Workers				
	1998	1999	2000	2001	2002
≥ 2	0	0	0	0	0
1.5 – 1.999	0	0	0	0	3
1.000 – 1.499	0	1	1	3	4
0.5 – 0.999	4	6	3	7	10
0.1 – 0.499	8	24	22	26	30
0.01 – 0.099	85	106	112	126	115
< 0.01	7,236	8,868	8,855	8,721	8,979
Total (Population) Worker Dose (person-rem)	**6.9**	**14.9**	**12.7**	**18.4**	**28.0**

Source: LLNL 2003as.

As seen in Table 4.16.2.2–1, the maximum individual worker dose for this period was less than 2 rem. Even with safety procedures and controls in place, inadvertent exposures can occur. There were no such occurrences from 1998 through 2001. There were two such instances in 2002; a worker's fingers were inadvertently exposed as a result of handling unsealed radioactive material, and a fissile material handler detected contamination on his hands after removing them from a glovebox. The worker population dose, when multiplied by the risk factor, implies that it is unlikely (0.02 cancers calculated for 2002 exposures) that an additional fatal cancer would result from occupational exposure at LLNL.

4.17 SITE CONTAMINATION AND REMEDIATION

This section describes the history, current status, and ongoing and planned remediation activities of contaminated soil and groundwater at LLNL. Separate discussions are presented for the Livermore Site and Site 300.

4.17.1 Site Contamination—Livermore Site

4.17.1.1 *Contamination History*

LLNL was founded at the Livermore Site in 1952 at a former U.S. Navy training base. Initial releases of hazardous materials occurred at the Livermore Site in the mid-to-late 1940s when the site was the Livermore Naval Air Station. There is also evidence that localized spills, leaking tanks and impoundments, and landfills contributed VOCs, fuel hydrocarbons, lead, chromium, and tritium to the groundwater and unsaturated sediment in the post-Navy era. The major contaminants are VOCs, primarily TCE. Environmental investigations and clean-up activities at the Livermore Site began in 1981. The Livermore Site was placed on the NPL in 1987 for cleanup under CERCLA. By the end of FY2006, DOE, depending on budget allocations, will have in place remediation facilities for long-term stewardship (in some cases, 50 to 60 years). The CERCLA environmental restoration treatment facilities and areas (see descriptions below) are shown in Figure 4.17.1.1–1. Contaminant release sites are assigned to 12 treatment facility (TF) areas, based on the nature and extent of contamination, infrastructure, and topographic and hydrologic considerations. The 12 areas are TFA, TFB, TFC, TFD, TFE, TFF406, TFG, TF518, TF5475, Building 331 area, Building 419/511 area, and Building 292 area. TF areas include both groundwater and vapor treatment facilities (VTFs). For 2002, the groundwater extraction wells operated at an average flow rate of 1,787 liters per minute; the vapor extraction average flow rate was 0.27 cubic meter per minute.

The objective of the TFs is to prevent the further movement of groundwater offsite, to remediate groundwater to drinking water standards, and to remediate the sources of contamination. Cleanup at each TF area includes groundwater monitoring, data analysis, and modeling. The results of the data analyses are used in decisionmaking for continued remediation optimization.

4.17.1.2 *Contamination Treatment Facilities and Areas*

Treatment Facility Area A

Treatment Facility Area A (TFA) is located in the southwest corner of the Livermore Site. Beginning operation in 1989, it is the oldest operating groundwater treatment system (GWTS) at the Livermore Site.

The TFA groundwater plumes affect approximately 98 acres, of which about 56 acres are located offsite. In 2002, TFA treated 251.4 million liters of groundwater, removing 5.7 kilograms of VOCs (Table 4.17.1.2–1). While the size of the offsite VOC plumes remained largely the same, the concentrations have declined below MCLs in most locations. The contaminants of concern are presented in Table 4.17.1.2–2.

TABLE 4.17.1.2–1.—*Volatile Organic Compounds Removed from Groundwater and Soil at the Livermore Site*

		2002		Cumulative Total	
Treatment Area	**Startup Date**	**Water Treated (million liters)**	**VOCs Removed (kilograms)**	**Water Treated (million liters)**	**VOCs Removed (kilograms)**
TFA	1989	251.4	5.7	3,658	154
TFB	1990	130.2	6.1	787	54.2
TFC	1993	107.9	7.1	595	53.9
TFD	1994	281.3	68.4	1,505	500
TFE	1996	110.5	17.5	544	139
TFG	1996	12.1	0.7	70.4	3.7
TF406	1996	40.5	1.0	211	7.7
TF518	1998	4.9	0.6	37.1	4.3
TF5475	1998	0.72	0.7	2.3	4.8
Total [a]		**939**	**108**	**7,410**	**922**
		Soil Vapor Treated (thousand cubic meters)	**VOCs Removed (kilograms)**	**Soil Vapor Treated (thousand cubic meters)**	**VOCs Removed (kilograms)**
VTF518	1995	0	0	425	153
VTF5475	1999	143.5	37.7	659	306
Total [a]		**144**	**38**	**1,084**	**459**

Source: LLNL 2003l.
[a] Rounded to nearest whole number.
TF = treatment facility; VOC = volatile organic compound; VTF = vapor treatment facility.

TFA was constructed to prevent VOCs from migrating downgradient toward municipal water supply wells to the west and agricultural and domestic wells to the south. Groundwater is treated using the large capacity air-stripping system installed in June 1997, replacing an ultraviolet hydrogen peroxide system. VOCs are stripped from the groundwater, and the effluent air from the stripper is passed through granular activated carbon filters to remove VOCs. The treated effluent air is then vented to the atmosphere. Another TF in the TFA uses granular activated carbon to remove VOCs and is solar powered.

In the TFA area, depth to groundwater is about 75 feet and groundwater flows to the west. Contaminants are generally confined from 75 to 140 feet below ground surface.

Treatment Facility Area B

Treatment Facility Area B (TFB) is located along Vasco Road on the western edge of the Livermore Site. TFB, which began operating in 1990, is the second oldest operating GWTS at the Livermore Site.

The TFB groundwater plumes affect approximately 27 acres, of which all are located onsite. In 2002, TFB treated 130.2 million liters of groundwater from six wells, removing 6.1 kilograms of VOCs (Table 4.17.1.2–1). The contaminants of concern are presented in Table 4.17.1.2–2.

TFB was constructed to prevent VOCs from migrating downgradient toward a residential area to the west. Groundwater is treated using a large capacity air-stripping system installed in October 1998. This unit replaced an ultraviolet/hydrogen peroxide system that had been in use since 1990. Groundwater is also treated for hexavalent chromium using an ion-exchange unit. Treated groundwater from TFB is discharged into the north-flowing drainage ditch parallel to Vasco Road, which empties into Arroyo Las Positas to the north.

TABLE 4.17.1.2–2.—*Contaminants of Concern, Including Sources, by Treatment Area*

Treatment Area	Brief Source[a] Description	Contaminants of Concern
TFA	Local storm drain outlets, spills into the retention tanks, and a transformer rupture	Primarily tetrachloroethylene and to a lesser degree TCE and 1,1-dichloroethylene
TFB	Local dumping of oils and solvents, open sewer lines, plating shop sumps, etc.	Primarily tetrachloroethylene and to a lesser degree TCE, 1,1-dichloroethylene, carbon tetrachloride, and other solvents. Hexavalent chromium is also present.
TFC	Releases from buildings, cooling tower discharges, tank leaks, etc.	Primarily tetrachloroethylene and TCE and to a lesser degree 1,1-dichloroethylene and chloroform. Hexavalent chromium is also present.
TFD	A number of sources including the old runways of the former Livermore Naval Air Station and landfills	TCE, trichlorofluoromethane, and other solvents. Hexavalent chromium is also present.
TFE	Underground storage tanks, oil, and chemical spills, etc.	TCE, tetrachloroethylene, and 1,1-dichloroethylene
TFF 406	Fuel and spills	Fuel hydrocarbons, toluene, benzene, etc. Chlorinated solvents are also present.
TFG	Floor drains, drum racks, potential releases from shops, spills, and leaking equipment	TCE and tetrachloroethylene
TF518	Accidental spills, solvent storage	Primarily tetrachloroethylene, TCE, and 1,1-dichloroethylene
TF5475	Former waste disposal pits and evaporation ponds	Tritium and chlorinated solvents.
Building 331	Tritium Facility operations	Tritium and solvents
Building 419/511	Former Navy aircraft assembly and maintenance operations	Primarily tetrachloroethylene, TCE, and carbon tetrachloride
Building 292	Former energy research facility	Tritium and VOCs

Source: LLNL 2003l.
[a] Source of contamination is based on best available information and may not be completely known.
TF = treatment facility; VOC = volatile organic compound.

Depth to groundwater is about 60 feet and groundwater flows to the west. Contaminants are generally confined from 60 to 120 feet below ground surface.

Treatment Facility Area C

Treatment Facility Area C (TFC) is located in the northwest part of the Livermore Site. TFC, which began operating in 1993, is the third oldest operating GWTS at the Livermore Site.

The TFC groundwater plume affects approximately 110 acres, all of which are located onsite. In 2002, TFC treated 107.9 million liters of groundwater, removing 7.1 kilograms of VOCs (Table 4.17.1.2–1). The contaminants of concern are presented in Table 4.17.1.2–2.

TFC was constructed to prevent VOCs from migrating downgradient toward a residential area to the west. TFC treats VOCs in groundwater using air stripping. The effluent air from the stripper is treated with granular activated carbon prior to discharge to the atmosphere. Groundwater is treated for hexavalent chromium using an ion-exchange unit. Treated groundwater from TFC is discharged into Arroyo Las Positas to the north.

The depth to groundwater is about 45 feet and groundwater flows to the west. Contaminants are generally confined from 45 to 65 feet below ground surface.

Treatment Facility Area D

Treatment Facility Area D (TFD) is located in the northeast quadrant of the Livermore Site. TFD, which began operating in 1994, is the fourth oldest operating GWTS at the Livermore Site.

The TFD groundwater plumes affect approximately 111 acres, all located onsite. In 2002, TFD treated 281.3 million liters of groundwater, removing 68.4 kilograms of VOCs (Table 4.17.1.2–1). The contaminants of concern are presented in Table 4.17.1.2–2.

TFD was constructed to prevent VOCs from migrating downgradient onsite and to clean up source areas near TFD. Fixed and portable TFs, operating in the TFD area, process VOCs in groundwater using air stripping. The effluent air from the air strippers is treated with granular activated carbon prior to discharge to the atmosphere. Treated groundwater from TFD is discharged either into the Drainage Retention Basin (DRB), into an underground pipeline downstream of the DRB weir, into a nearby storm sewer, or into drainage ditches, each flowing north into the DRB. All discharge eventually empties into Arroyo Las Positas.

Depth to groundwater is about 70 feet and groundwater flows to the west. Contaminants are generally confined from 70 to 140 feet below ground surface.

Treatment Facility Area E

Treatment Facility Area E (TFE) is located in the central eastern part of the Livermore Site. TFE, which began operating in 1996, is one of three operating GWTSs that were activated in 1996 at the Livermore Site.

The TFE groundwater plumes affect approximately 42 acres, located onsite. In 2002, TFE treated 110.5 million liters of groundwater, removing 17.5 kilograms of VOCs (Table 4.17.1.2–1). The contaminants of concern are presented in Table 4.17.1.2–2.

TFE was constructed to prevent VOCs from migrating downgradient onsite and to clean up nearby contaminant source areas. VOCs are treated using an air stripper. Before the effluent air is vented to the atmosphere, it is treated using granular activated carbon to remove VOCs. Treated groundwater is discharged into a drainage ditch that flows north into the DRB.

Depth to groundwater is about 75 feet and groundwater flows to the west. Contaminants are generally confined from 75 to 120 feet below ground surface.

Treatment Facility Area F 406

Treatment Facility Area F 406 (TFF406) is located in the central southern area of the Livermore Site. TFF began operation in 1991 as a pilot study, testing vacuum-induced venting followed by stripping to remediate hydrocarbons at the site of an old gasoline station. By 1996, the vadose (unsaturated) zone remediation was complete and only residual concentrations of hydrocarbons remained in the saturated zone. No further action status for hydrocarbons was granted in 1996. TFF406 began operating in 1996 to treat VOCs as one of three GWTSs activated in 1996 at the Livermore Site. Treated groundwater is discharged into storm drains leading to Arroyo Las Positas.

There is no unsaturated zone soil contamination in the TFF406 area requiring remediation. The TFF406 groundwater VOC plume is approximately 9 acres and is located onsite and south of East Avenue (extending offsite by approximately 750 feet), including a portion of the SNL/CA site. In 2001, TFF 406 treated 40.5 million liters of groundwater, removing 1.0 kilogram of VOCs (Table 4.17.1.2–1). The contaminants of concern are presented in Table 4.17.1.2–2.

TFF406 was constructed to prevent VOCs from migrating downgradient toward municipal water supply wells to the west and agricultural wells and domestic wells to the south. TFF406 uses an air stripper to treat VOCs in groundwater. Granular activated carbon removes VOCs from effluent air prior to discharge to the atmosphere. All treated groundwater is discharged to an underground storm drain that flows north to Arroyo Las Positas.

Depth to groundwater is about 100 feet and groundwater flows to the west. Contaminants are generally confined from 150 to 190 feet below ground surface.

Treatment Facility Area G

Treatment Facility Area G (TFG) is located in the central south region of the Livermore Site. TFG, which began operating in 1996, is one of three operating GWTSs activated in 1996 at the Livermore Site.

The TFG groundwater plumes affect approximately 77 acres, all located onsite. In 2002, TFG treated 12.1 million liters of groundwater, removing 0.7 kilogram of VOCs (Table 4.17.1.2–1). The contaminants of concern are presented in Table 4.17.1.2–2.

TFG was constructed to prevent VOCs from migrating downgradient onsite. Depth to groundwater is about 70 feet and groundwater flows to the west. Contaminants are generally confined from 70 to 90 feet below ground surface.

Treatment Facility Area 518

Treatment Facility Area 518 (TF518) is located in the southeast corner of the Livermore Site. TF518, which began operating in 1998, is one of several recent additions to operating GWTSs at the Livermore Site.

The TF518 groundwater plume affects approximately 15 acres, most located onsite. The remainder extends south of East Avenue by several hundred feet, including a portion of the

SNL/CA site. In 2002, TF518 treated 4.9 million liters of groundwater, removing 0.6 kilogram of VOCs (Table 4.17.1.2–1). The contaminants of concern are presented in Table 4.17.1.2–2.

TF518 was constructed to prevent VOCs from migrating downgradient toward SNL/CA to the south. Depth to groundwater is about 110 feet and groundwater flows to the west. Contaminants are generally confined from 110 to 130 feet below ground surface.

Treatment Facility Area 5475

Treatment Facility Area 5475 (TF5475) is located in the southeastern region of the Livermore Site. TF5475, which began operating in 1998, is one of several recent additions to operating GWTSs at the Livermore Site.

The TF5475 groundwater plumes affect approximately 11 acres, all located onsite. In 2002, TF5475 treated 0.38 million liters of groundwater, removing 0.7 kilograms of VOCs (Table 4.17.1.2–1). Also, tritium concentrations remained below the MCL and continued to decrease. The contaminants of concern are presented in Table 4.17.1.2–2.

TF5475 was constructed to prevent VOCs and tritium from migrating downgradient toward SNL/CA to the south and remediate contaminant sources in the area. Depth to groundwater is about 85 feet and groundwater flows to the west. Contaminants are generally confined from 85 to 130 feet below ground surface.

Building 331 Area

Environmental restoration activities in the Building 331 area, located in the south-central region of the Livermore Site, include groundwater monitoring and sampling. Building 331, which began operating in 1959, once provided primary support to the LLNL weapons program. The main effluent releases from this building were gaseous tritium discharges through 100-foot-high stacks. NNSA expects no active soil vapor treatment system will be required as the tritium naturally decays.

The Building 331 area groundwater plume affects approximately 2 acres; the entire plume is located in the vicinity of Building 331, also referred to as the Tritium Facility. The primary contaminant of concern is tritium as presented in Table 4.17.1.2–2.

The Building 331 area is monitored for tritium migration. Depth to groundwater is about 70 feet. Tritium is generally confined to this depth and the vadose (unsaturated) zone.

Building 419/511 Area

Environmental restoration activities in the Building 419/511 area, located in the southeastern quadrant of the Livermore Site, include groundwater monitoring and sampling. The area was part of the former Naval Site, where aircraft assembly and maintenance was completed. Building 419 was used as an assay lab and then as a decontamination and size reduction facility by the RHWM Division, for which a partial RCRA closure was completed. NNSA expects to continue to monitor the area until cleanup standards are reached or the building is demolished or decommissioned.

The Building 419/511 area groundwater plume affects approximately 3 acres, located near Building 419/511. The contaminants of concern are presented in Table 4.17.1.2–2. VOCs removed at Building 419/511 are included in the TF518 results on Table 4.17.1.2–1.

Building 292 Area

Environmental restoration activities in the Building 292 area, located in the northwestern part of the Livermore Site, include tritium monitoring and sampling around the building. Building 292 housed a rotating target neutron source that was used for energy research. DOE expects to continue to monitor the area until cleanup standards are reached.

The Building 292 area groundwater plume affects approximately 3 acres, all located in the vicinity of Building 292. Tritium is the primary contaminant of concern (Table 4.17.1.2–2).

Spills

Small, localized chemical, oil, or hazardous material spills or releases have occurred at the site in the past. The possibility of a spill occurring still exists, given the variety of materials handled at LLNL. Some buildings use a variety of chemicals, including solvents, paints, and industrial gases (Section 4.15.1); however, industry-accepted controls are in place to minimize the potential for soil contamination from any ongoing LLNL operations.

The RHWM Division stores, treats, and handles hazardous and radioactive wastes prior to shipment offsite for disposal. These facilities have the potential for hazardous spills, releases, or fires. The RHWM Division is responsible for maintaining control and countermeasures to prevent and protect the environment in accordance with the site's hazardous waste permit. At the waste management facilities, industry-accepted controls are in place to minimize the potential for soil contamination from any LLNL waste management facility operations.

4.17.1.3 *Remedial Actions*

Status of Remediation Efforts

Since remediation began in 1989, the concentrations within the Livermore Site VOC plumes has been decreasing (Figure 4.17.1.3–1). Most of the observed trends in VOC concentrations are attributed to active groundwater extraction and remediation. Notable results of VOC analyses of groundwater are discussed below.

VOC concentrations on the western margin of the site either declined or remained unchanged during 2002, indicating continued hydraulic control of the western site boundary plumes in the TFA, TFB, and TFC. Concentrations in the TFA and TFB source areas increased slightly, however. The entire offsite Hydrostratigraphic Unit 2 plume from TFA dropped below 50 parts per billion for the first time (hydrostratigraphic units are shown in Figure 4.17.1.1–1).

In TFB, VOC concentrations were lower in Hydrostratigraphic Unit 1B close to Vasco Road, where TCE declined from 23 parts per billion in 2001 to 14 parts per billion in 2002.

In the central to northern parts of TFC, the lateral extent of Hydrostratigraphic Unit 1B total VOC concentrations above 50 parts per billion decreased significantly. Total VOC concentrations decreased along the western margin of TFC.

Concentrations began to decline in 2002 in a Hydrostratigraphic Unit 2 plume located in the western part of TFE in response to pumping. TCE declined from 220 parts per billion in 2001 to 76 parts per billion in one extraction well in 2002.

Hydrostratigraphic Unit 3A total VOC concentrations continued to decline in the T5475 area in 2002 due to a combination of soil vapor extraction and regional dewatering of Hydrostratigraphic Unit 3A. VOCs in Hydrostratigraphic Units 3A, 3B, and 4 declined in the south-central part of TFD in response to pumping. Hydrostratigraphic Unit 4 TCE concentrations also declined in the southwestern part of TFE due to ongoing pumping.

Significant decreases in Hydrostratigraphic Unit 5 VOC concentrations were observed in TFF406 during 2002 in response to groundwater extraction, particularly at SNL/CA south of East Avenue. TCE in one well at the leading edge of a TCE plume, declined from 27 parts per billion in 2001 to less than 0.5 part per billion in 2002. Closer to TFF406, TCE in one well declined from 31 parts per billion to 9 parts per billion over the same period.

Proposed Remedial Actions

LLNL and NNSA believe that the following proposed major milestones would continue to best meet the criteria established in the original 1992 CERCLA Record of Decision (ROD) for this site (DOE 1992a) and the most recent five-year review:

FY2004

- Begin Helipad source area remediation
- Begin TF518 perched-zone remediation
- Begin Southern East Traffic Circle source area remediation

FY2005

- Begin TFD hotspot remediation
- Begin TFE hotspot remediation
- Begin Northern East Traffic Circle source area remediation
- Begin TF406 hotspot remediation

FY2006

- Begin Building 419 source area remediation
- Begin TF406 South remediation

- Begin TFB/C source area remediation
- Begin Buildings 511/514 source area remediation
- Begin TF5475 South remediation

By the end of FY2006, NNSA expects that approximately 38 groundwater remediation systems will be in place. NNSA's ongoing investigations are focused on identifying all remaining sources of groundwater contamination. The goals of groundwater remediation are to remove contaminant mass, reduce contaminant concentrations, and contain the migration of the plumes. NNSA will continue to operate pump treat systems until cleanup levels are achieved. NNSA plans to manage remedial sites as part of the site-wide long-term stewardship effort.

4.17.2 Site Contamination—Site 300

4.17.2.1 *Contamination History*

LLNL Site 300 is a NNSA experimental test facility that conducts research, development, and testing associated with high explosives materials. During past Site 300 operations, contaminants were released to the environment from surface spills and pipe leaks, leaching from unlined landfills and pits, high explosive test detonations, and disposal of waste fluids in lagoons and dry wells. LLNL began environmental investigation and restoration activities in 1981, and the site was placed on the NPL in 1990. The primary contaminants of concern at Site 300 include VOCs, high explosive compounds, perchlorate, tritium, depleted uranium, nitrate, PCBs, dioxins, furans, silicone oils, and metals (Table 4.17.2.1–1).

All contaminant release sites at Site 300 are assigned to one of eight operable units (OUs) (see Figure 4.11.3.4–2), based on the nature and extent of contamination and hydrogeologic considerations. More detailed background information for Site 300 environmental characterization activities may be found in the *Final Site-wide Remedial Investigation Report*, *Lawrence Livermore National Laboratory Site 300* (LLNL 1994a, LLNL 1994b), and the *Final Site-wide Feasibility Study*, *Lawrence Livermore National Laboratory Site 300* (LLNL 1999d).

In 2001, NNSA and the regulatory agencies signed an interim site-wide ROD in which interim remedial actions were selected for the cleanup of Site 300. This ROD was designated as interim to ensure remediation activities commence while additional testing and evaluation of cleanup technologies occur and final groundwater cleanup standards are negotiated. The overall NNSA/LLNL remedial strategy for Site 300 is to achieve a rapid, efficient, and cost-effective cleanup within budgetary constraints and in compliance with regulatory requirements. The selected interim remedies are being implemented in phases using a prioritized, risk-based approach.

More detailed information for the interim remedial actions at Site 300 may be found in the *Interim Site-wide Record of Decision*, *Lawrence Livermore National Laboratory Site 300* (LLNL 2001u), and the *Remedial Design Work Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300* (LLNL 2001i).

TABLE 4.17.2.1–1.—*Major Groundwater Contaminants of Concern at Site 300*

Operable Unit (OU)	Contaminant(s) of Concern
General Services Area (GSA) (OU1)	VOCs (primarily TCE)
Building 834 Complex (OU2)	VOCs (primarily TCE), organosilicate oil, nitrate
High Explosives Process Area (OU4)	VOCs (primarily TCE), high explosive (primarily RDX), nitrate, perchlorate
Building 850/Pits 3 and 5 (OU5)	Tritium, depleted uranium, VOCs (primarily TCE), nitrate, perchlorate
Building 854 (OU6)	VOCs (primarily TCE), nitrate, perchlorate
Pit 6 (OU3)	VOCs (primarily TCE), tritium, nitrate, perchlorate
Building 832 Canyon (OU7)	VOCs (primarily TCE), nitrate, perchlorate
Site 300 (OU8)	VOCs (primarily TCE and Freon 113), nitrate, perchlorate, depleted uranium, tritium metals, RDX

Source: LLNL 2003l.
RDX = cyclo-1, 3, 5 – trimethylene – 2, 4, 6 - trinitramine; TCE = trichloroethene; VOC = volatile organic compound

4.17.2.2 *Operable Units*

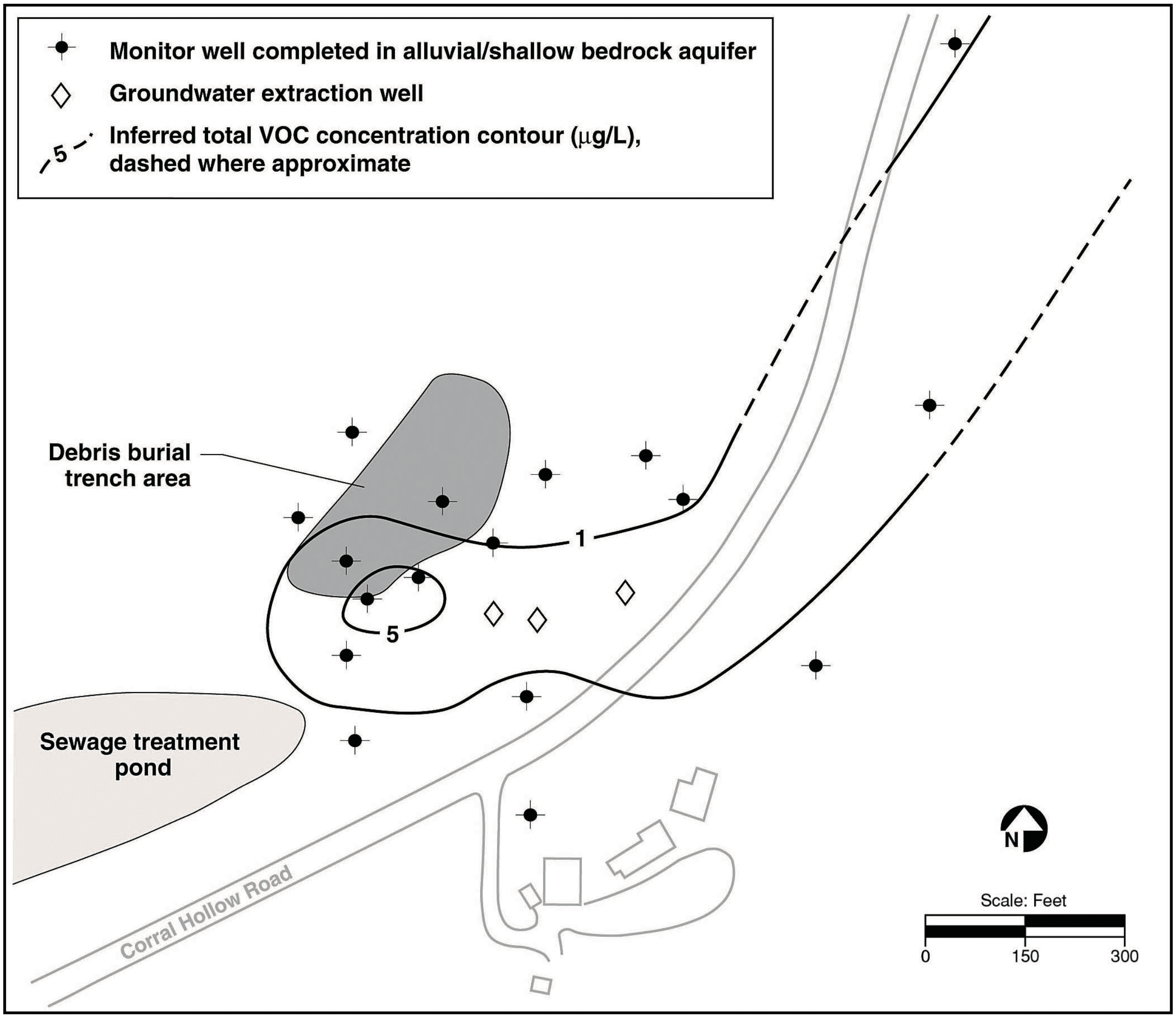
The following sections briefly summarize background information and characterization activities for each of the operable units.

General Services Area Operable Unit

TCE and other solvent-related VOCs were released to the soil and groundwater as a result of past activities in the craft shops and equipment fabrication and repair facilities in the GSA. For the purposes of remediation management, the GSA has been subdivided into the eastern and central GSA subareas, based on differences in contaminant sources and hydrogeology. The eastern and central GSA subareas are discussed individually below.

Eastern General Services Area

In the eastern GSA, the highest VOC concentrations in groundwater occur in the vicinity of a former debris burial trench area where craft shop debris was disposed of in the 1960s and 1970s. A VOC groundwater plume, shown in Figure 4.17.2.2–1, extends approximately 1,400 feet east and northeast of the burial trench area in the direction of alluvial groundwater flow. The depth to groundwater in this area is 10 to 30 feet below ground surface. The maximum total VOC concentration detected in groundwater collected from eastern GSA wells in the fourth quarter of 2002 was 7.5 micrograms per liter (LLNL 2003l).



Source: LLNL 2003l.

FIGURE 4.17.2.2–1.—*Total Volatile Organic Compound Concentrations in Groundwater in the Eastern General Services Area and Vicinity (Fourth Quarter, 2002)*

In 1991, an extraction and treatment system was installed and began to remove VOCs from groundwater. In 1997, an area-specific ROD was signed in which a remedial action for the cleanup of the eastern GSA was selected. The selected remedy includes continued groundwater vapor extraction and treatment. The volume of groundwater treated and mass of VOCs removed by the eastern GSA facility through 2002 are presented in Table 4.17.2.2–1. The eastern GSA treatment facility effluent discharge is regulated under an NPDES permit issued by the Central Valley RWQCB.

Before treatment commenced in 1991, a TCE groundwater plume extended more than a mile offsite. By 2001, the TCE plume, as defined by the 5-micrograms-per-liter TCE isoconcentration contour, was contained onsite with only two onsite wells containing TCE at concentrations slightly above the safe drinking water standard of 5 micrograms per liter. The effectiveness of the remediation effort in the eastern GSA is reevaluated every 5 years in the GSA Five-Year Review report (LLNL 2001ba).

TABLE 4.17.2.2–1.—*Volatile Organic Compounds Removed from Groundwater and Soil Vapor at Site 300 through 2002*

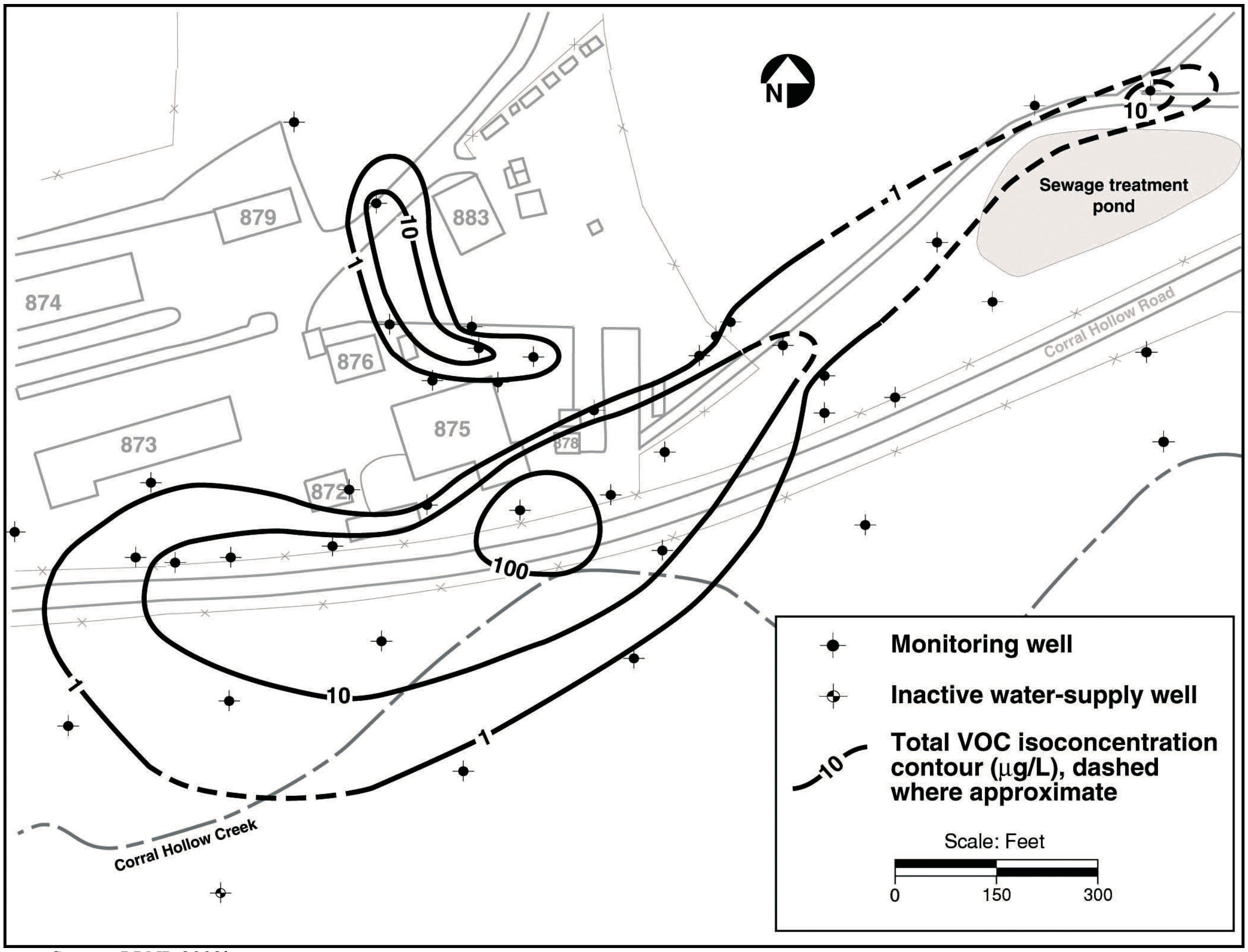
Treatment Area	2002			Cumulative Total	
	Startup Date	**Water Treated (million liters)**	**VOCs Removed (kilograms)**	**Water Treated (million liters)**	**VOCs Removed (kilograms)**
Eastern GSA	1991	78.7	0.17	806.6	6.19
Central GSA	1993	4.19	0.59	29.16	10.66
Building 834	1995	0.11	0.81	0.93	31.84
High Explosives Process Area	1999	4.5	0.012	10.5	0.058
Building 832	1999	1.90	0.12	5.68	0.44
Building 854	1999	3.67	0.78	12.25	6.14
Pit 6	1998	Not Applicable	Not Applicable	0.268	0.0014
Total		**93.1**	**2.48**	**865.4**	**55.33**
		Soil Vapor Treated (thousand cubic meters)	**VOCs Removed (kilograms)**	**Soil Vapor Treated (thousand cubic meters)**	**VOCs Removed (kilograms)**
Central GSA	1994	293.58	1.54	1,987.18	66.16
Building 834	1998	406.18	5.19	1,657.56	108.26
Building 832	1999	96.2	0.28	282.5	1.39
Total		**795.96**	**7.01**	**3,927.44**	**175.81**

Source: LLNL 2003l.
GSA = General Services Area; VOC = volatile organic compound.

Central General Services Area

In the central GSA, VOCs were released to the ground in wastewater from the craft and repair shops and as leaks/spills from solvent storage tanks or drums. TCE typically comprises 85 to 95 percent of the total VOCs detected in the subsurface. These releases originally affected approximately 33,900 cubic yards of soil onsite. Two VOC plumes in the central GSA, shown in Figure 4.17.2.2–2, are present in groundwater at a depth of 10 to 30 feet below ground surface. The northern plume is approximately 350 feet long and is contained onsite. The plume located south of Building 875 is approximately 1,600 feet long and extends about 250 feet offsite. TCE concentrations in groundwater in the central GSA area have decreased over time from an historical maximum of 240,000 micrograms per liter to 958 micrograms per liter in 2002. VOC concentrations in soil/bedrock have also been significantly reduced.

In 1995, an extraction and treatment system was installed in the central GSA to remediate VOCs in both soil/bedrock and groundwater. In 1997, an area-specific ROD was signed in which the remedial action for the cleanup of the central GSA was selected. The selected remedy includes continued groundwater and soil vapor extraction (SVE) and treatment. The volume of groundwater and soil vapor treated and mass of VOCs removed by the central GSA facility through 2002 are presented in Table 4.17.2.2–1. The central GSA treatment facility effluent discharge is regulated under Substantive Requirements for Wastewater Discharge issued by the Central Valley RWQCB. The effectiveness of the remediation effort in the central GSA is reevaluated every five years in the GSA Five-Year Review report (LLNL 2001ba).



Source: LLNL 2003l.

FIGURE 4.17.2.2–2.—*Total Volatile Organic Compound Concentrations in Groundwater in the Central General Services Area (Fourth Quarter, 2002)*

Building 834, Operable Unit 2

Facilities at the Building 834 Complex have been used since the late 1950s to conduct thermal-cycling experiments on weapon components. Aboveground pipes carried TCE-based heat-exchange fluid from the main buildings to and from surrounding test cells. Occasionally, TCE was mixed with silicone oil to prevent the degradation of pump seals and gaskets.

From 1962 to 1978, intermittent spills and piping leaks resulted in the contamination of the subsurface bedrock and shallow groundwater with TCE and silicone oils. These releases originally affected approximately 33,900 cubic yards of soil. The TCE groundwater contamination extends approximately 1,100 feet downgradient from the source area in several discrete, shallow, perched, water-bearing zones as shown in Figure 4.17.2.2–3. TCE concentrations in groundwater in the Building 834 area have decreased over time from an historical maximum of 800,000 micrograms per liter to 87,000 micrograms per liter in 2002. Nitrate contamination in groundwater results from septic system effluent but may also have natural sources.

In 1995, an extraction and treatment system was installed that simultaneously extracts contaminated soil vapor and groundwater from the subsurface. Studies have shown that natural biodegradation of TCE through anaerobic dehalogenation has been occurring in the source area of Building 834. Treatability studies, focusing on understanding and enhancing the bioremediation process, are underway.

An area-specific interim ROD was signed in 1995 that was superceded by the interim site-wide ROD in 2001. The selected interim remedy for Building 834 includes continued groundwater and SVE and treatment using an expanded well field. The volume of groundwater and soil vapor treated and mass of VOCs removed by the Building 834 facility through 2002 are presented in Table 4.17.2.2–1. The Building 834 treatment facility effluent discharge is regulated under Substantive Requirements for Wastewater Discharge issued by the Central Valley RWQCB. A five-year review was completed in 2002 to reevaluate the effectiveness of the remediation effort in the Building 834 operable unit (LLNL 2001ab).

High Explosives Process Area, Operable Unit 4

The High Explosives Process Area was established in the 1950s to chemically formulate, mechanically press, and machine high explosive compounds into detonation devices that are tested in explosive experiments at Site 300. The High Explosives Process Area Operable Unit includes Building 815, high explosive lagoons, high explosive burn pit release sites, and related downgradient groundwater plumes. Depth to groundwater in the High Explosives Process Area ranges from 30 to 250 feet below ground surface.

Surface spills at the former Building 815 steam plant resulted in TCE contaminant plumes that extend up to 3,000 feet from the source area (Figure 4.17.2.2–4). VOC concentrations in the Building 815 area have decreased over time from an historical maximum of 1,000 micrograms per liter to 80 micrograms per liter in 2002. In 1999, a groundwater extraction and treatment system was installed at the site boundary to prevent offsite migration of the TCE plume. In 2000 and 2002, additional extraction and treatment systems were installed at and downgradient from the Building 815 source area to remove TCE mass and prevent further plume migration.

From the late 1950s to 1985, wastewater containing high explosive compounds, nitrate, and perchlorate was discharged to unlined rinse water lagoons. These lagoons are thought to be the primary source of high explosive compounds, nitrate, and perchlorate in groundwater. The plumes of high explosive compounds and perchlorate extend approximately 700 and 2,000 feet, respectively, downgradient from the lagoon source area. High explosive compound concentrations have decreased with time. There is evidence that the nitrate present in groundwater is naturally attenuated through denitrification processes in the aquifer. The former rinse water lagoons were capped and closed in 1989 to prevent further releases of high explosive compounds and associated constituents (nitrate and perchlorate).

From the late 1950s to 1998, three burn pits were used to burn high explosive particulates and cuttings, explosive chemicals, and explosives-contaminated debris. High explosive compounds have been detected at low levels in soil but do not present a risk to human health or threat to groundwater. Groundwater data indicate that TCE, believed to be from a spill at an adjacent waste storage area, has affected groundwater. The high explosive burn pits were capped and closed under RCRA in 1998.

The selected interim remedy for the High Explosives Process Area Operable Unit includes continued and expanded groundwater extraction and treatment. The volume of groundwater and soil vapor treated and the mass of VOCs removed by the High Explosives Process Area treatment facilities through 2002 are presented in Table 4.17.2.2–1. The High Explosives Process Area treatment facility effluent discharges are regulated under Substantive Requirements for Wastewater Discharge issued by the Central Valley RWQCB.

Building 850/Pits 3 and 5, Operable Unit 5

The Building 850/Pits 3 and 5 Operable Unit includes the Building 850 firing table and sand pile, landfill Pits 3 and 5, and groundwater plumes originating at the Building 850 release site and Landfill Pits 2, 3, 5, and 7.

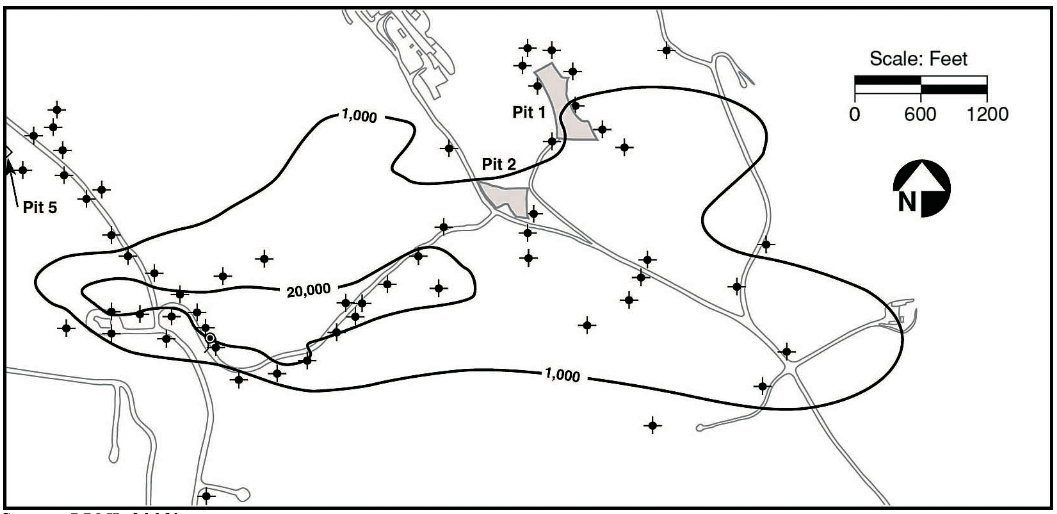
The Building 850 firing table has been used to conduct high explosive experiments since 1958. Tritium was used in some of these experiments, primarily between 1963 and 1978. As a result of the destruction and dispersal of test assembly debris during detonations, surface soil was contaminated with metals, PCBs, dioxins, furans, cyclotetramethylene tetranitramine, and depleted uranium. Leaching from firing table debris has resulted in tritium and depleted uranium in groundwater. Nitrate has also been identified in groundwater.

Gravel was removed from the firing table in 1988 and placed in the Pit 7 landfill. PCB-contaminated shrapnel and debris were removed from the area around the firing table in 1998. The selected remedy for the Building 850 area includes the excavation of the contaminated surface soil and a nearby sand pile as a final remedy and monitored natural attenuation of tritium in groundwater as an interim remedy.

Landfill Pits 3 and 5 were used from 1958 to 1967 to dispose of firing table debris and from 1968 to 1979, to dispose of firing table gravel. VOCs, tritium, depleted uranium, nitrate, and perchlorate were released from these landfills as a result of leaching of these contaminants from the pit waste. Data indicate continued releases of tritium are occurring as groundwater rises into the pits during high rainfall years (i.e., during El Niño). TCE concentrations in groundwater in the vicinity of the Pit 5 release area have decreased to below drinking water standards (5 micrograms per liter).

Depth to groundwater ranges from 15 to 65 feet below ground surface in Operable Unit 5. The tritium emanating from Pits 3 and 5 flows to the south-southeast in shallow alluvial groundwater and commingles with the tritium plume emanating from Building 850 (Figure 4.17.2.2–5). The total length of the commingled tritium plume is about 10,000 feet. Tritium has also been detected in bedrock groundwater that flows northeast of the pits. Concentrations of depleted uranium in groundwater near Pits 3 and 5 remain above drinking water standards while depleted uranium levels in groundwater in the vicinity of Building 850 are well below drinking water standards.

A remedial investigation/feasibility study is in progress for the Pits 3 and 5 areas. Source isolation and containment technologies are being evaluated to prevent further releases of tritium and uranium from the pits to groundwater. An amendment to the interim site-wide ROD is scheduled for 2006 in which a remedy for the Pits 3 and 5 areas will be selected.



Source: LLNL 2003l.

FIGURE 4.17.2.2–5.—*Distribution of Tritium in Groundwater in the First Water-Bearing Zone in Building 850/Pits 3 and 5 Operable Unit (Second Quarter, 2002)*

Building 854, Operable Unit 6

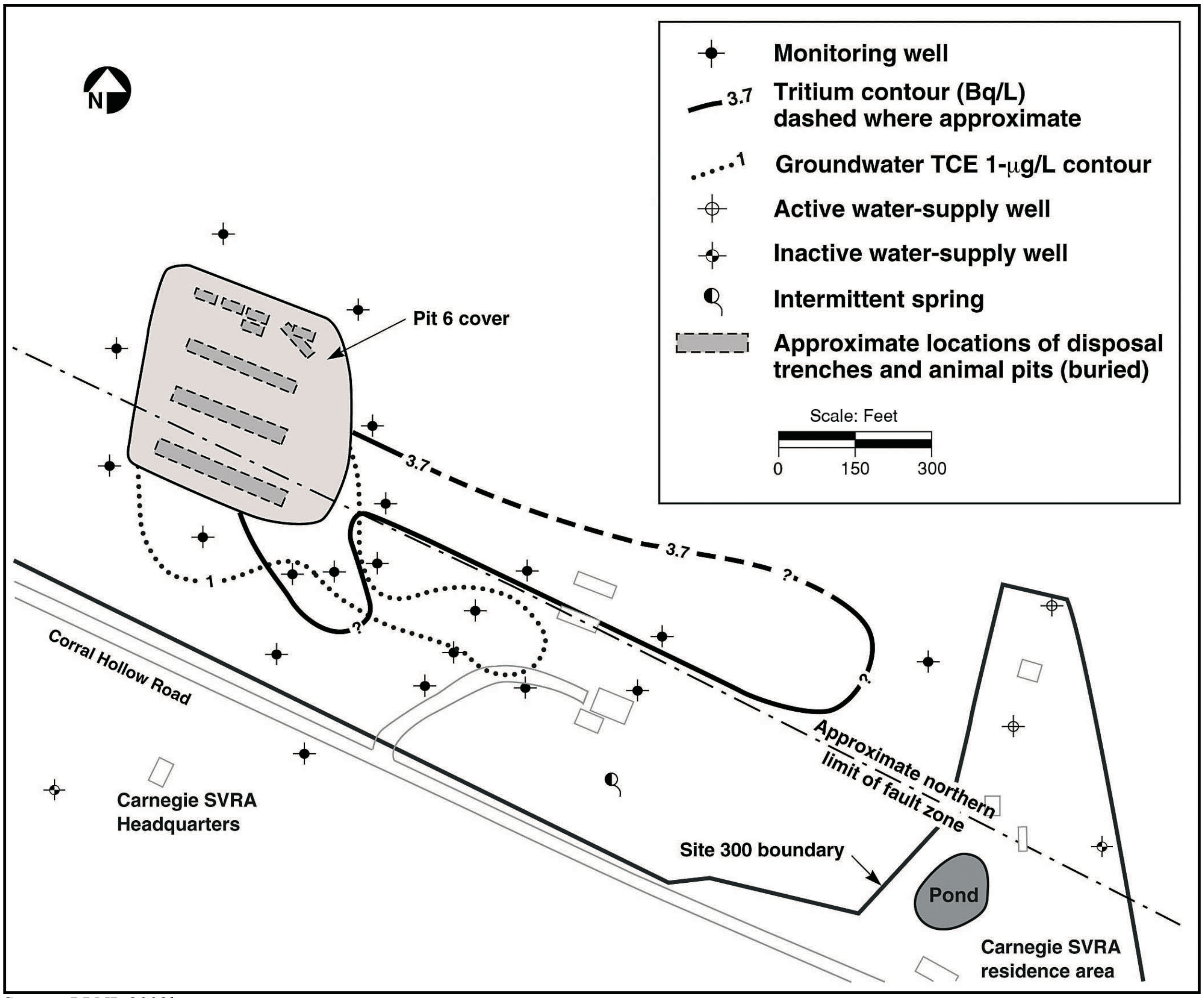
Facilities at the Building 854, 855, 856, and 857 complex were used between 1959 and 1970 to test the stability of weapons and weapon components under various environmental conditions and mechanical and thermal stresses. TCE was released to soil and groundwater through leaks and discharges of TCE-based heat exchange fluids from the brine system at Buildings 854D, E, and F. Discharge at the Building 854H drain outfall also resulted in releases of TCE to the ground surface. As a result, a plume of TCE extends approximately 3,000 feet from the Building 854 complex source area (Figure 4.17.2.2–6). The affected aquifer occurs at depths of 10 to 180 feet below ground surface. TCE concentrations in groundwater in the Building 854 area have decreased over time from an historical maximum of 2,900 micrograms per liter to 270 micrograms per liter in 2002. A septic system, located east of Building 855A, may have released nitrate to groundwater, although natural sources are likely to have contributed to nitrate mass as well. Perchlorate has also been detected in groundwater at concentrations exceeding the state action level.

The TCE brine system was removed in 1989. TCE-contaminated soil was excavated in 1983 in the vicinity of the Building 854H drain outfall and near Building 854F. Extraction and treatment systems were installed at and downgradient from the Building 854 source area in 1999 and 2000, respectively, to remove VOCs, nitrate, and perchlorate from the groundwater. The selected interim remedy for Building 854 includes groundwater and SVE and treatment. The volume of groundwater and soil vapor treated and mass of VOCs removed by the Building 854 treatment facilities through 2002 are presented in Table 4.17.2.2–1. The Building 854 treatment facility effluent discharges are regulated under Substantive Requirements for Wastewater Discharge issued by the Central Valley RWQCB.

Pit 6, Operable Unit 3

From 1964 to 1973, approximately 1,900 cubic yards of waste from the Livermore Site and Lawrence Berkeley National Laboratory were buried in 9 unlined trenches and animal pits at the Pit 6 landfill. As a result of rainwater percolating through the waste, VOCs (primarily TCE), tritium, nitrate, and perchlorate were released to the subsurface. These contaminants are present onsite in a shallow water-bearing zone approximately 80 feet below ground surface. VOC concentrations in groundwater have naturally attenuated by almost two orders of magnitude over the past few years and are near or below drinking water standards in all wells. Tritium activities exceed background in several wells, indicating a possible localized release. Maximum historical tritium activities in groundwater are well below the drinking water standard of 20,000 picocuries per liter. The extent of TCE in groundwater is shown in Figure 4.17.2.2–7. Perchlorate has been detected in several wells at concentrations above the state action level of 4 micrograms per liter.

In 1971, DOE/LLNL excavated portions of the waste contaminated with depleted uranium. In 1997, an engineered landfill cap was installed as a CERCLA removal action to prevent infiltrating precipitation from further leaching contaminants from the waste. Because of the decreasing TCE concentrations in groundwater, and the short half-life of tritium (12.3 years), the selected interim remedy for TCE and tritium at the Pit 6 landfill is monitored natural attenuation. During the period covered by the interim site-wide ROD, NNSA will continue evaluating the source, extent, and natural degradation of perchlorate and nitrate at the Pit 6 landfill. The interim remedy for these substances in groundwater is continued monitoring.



Source: LLNL 2003l.

FIGURE 4.17.2.2–7.—*Distribution of TCE in Groundwater in the Pit 6 Area (Fourth Quarter, 2002)*

Building 832 Canyon, Operable Unit 7

Contaminants, primarily VOCs, were released from Buildings 830 and 832 from the late 1950s to 1985 through piping leaks and surface spills. TCE was used as a heat exchange fluid as part of testing activities at these buildings. TCE concentrations in groundwater in the Building 830 area have decreased over time from an historical maximum of 30,000 micrograms per liter to 12,000 micrograms per liter maximum in 2002. As shown in Figure 4.17.2.2–8, TCE plumes extend approximately 4,600 feet downgradient from Buildings 830 and 832. Depth to groundwater ranges from 15 to 200 feet in this OU.

Nitrate and perchlorate are also present in groundwater at both Buildings 830 and 832. Nitrate contamination in groundwater may be the result of a combination of high explosive related testing and septic system releases, with a possible contribution from naturally occurring nitrate from local geologic units. High explosive compounds released may have degraded and migrated downward as nitrogenous compounds. Although the source of perchlorate is not known at this time, it may be that perchlorate was a component of high explosive test assemblies.

A groundwater and SVE and treatment system was installed at the Building 832 source area in 1999. Extraction and treatment systems were installed downgradient from the Building 830 source area and near the site boundary in 2000 to remove contaminant mass from groundwater and prevent the offsite migration of the plumes. The selected remedy for Buildings 830 and 832 includes continued soil vapor and groundwater extraction and treatment. The volume of groundwater and soil vapor treated and mass of VOCs removed by the Building 832 Canyon treatment facilities through 2002 are presented in Table 4.17.2.2–1. The Building 832 Canyon treatment facility effluent discharges are regulated under Substantive Requirements for Wastewater Discharge issued by the Central Valley RWQCB.

Site 300 Site-wide, Operable Unit 8

The Site 300 site-wide operable unit consists of several small release sites where active remediation is not required. These release sites include the Building 801D dry well and Pit 8 landfill, Building 833, the Building 845 firing table and Pit 9 landfill, and the Building 851 firing table.

Building 801D Dry Well and the Pit 8 Landfill

Waste fluid was discharged to a dry well located adjacent to Building 801D from the late 1950s to 1984, resulting in minor subsurface VOC contamination. VOC concentrations in groundwater are within drinking water standards. The dry well was decommissioned and filled with concrete in 1984. The adjacent Pit 8 landfill received debris from the Building 801 firing table until 1974, when it was covered with compacted soil. No contaminants have been detected in the vicinity of the landfill. The selected interim remedy for Building 801 and the Pit 8 landfill is enhanced vadose zone and groundwater monitoring of VOC concentrations to detect any future releases from the landfill.

Building 833

TCE was used as a heat-exchange fluid in the Building 833 area from 1959 to 1982 and was released through spills and rinse water disposal, resulting in minor VOC contamination of the shallow soil and perched, ephemeral groundwater. VOC concentrations have decreased over time, likely due to natural attenuation. The selected interim remedy for Building 833 is continued groundwater monitoring to ensure that TCE continues to attenuate.

Building 845 Firing Table and Pit 9 Landfill

High explosive experiments were conducted at the Building 845 firing table from 1958 to 1963. Leaching from firing table debris resulted in minor contamination of subsurface soil with depleted uranium and cyclotetramethylene tetranitramine. No groundwater contamination has been detected. Debris and gravel from the Building 845 firing table were routinely placed in the adjacent Pit 9 landfill. No unacceptable risk to human health has been associated with the Pit 9 landfill and there is no evidence of any release from the landfill. The selected interim remedy for the Building 845 firing table and Pit 9 landfill is enhanced vadose zone and groundwater monitoring to detect any future releases from the landfill.

Building 851 Firing Table

The Building 851 firing table has been used for high explosive research since 1982. These experiments resulted in minor VOC, depleted uranium, metals, and the high explosive compound cyclo-1,3,5-trimethylene-2,4,6-trinitramine (RDX) contamination in soils and groundwater. Contaminant concentrations in groundwater are below drinking water standards. No unacceptable risk to human health has been associated with contaminants in this area. In 1988, the firing table gravel was removed and has been replaced periodically since then. The selected interim remedy for Building 851 is continued groundwater monitoring to ensure that contaminant concentrations do not increase to a level presenting risk.

Continuing Characterization

Additional characterization is underway or planned at Building 865 (Advanced Test Accelerator), Building 812, and the former Sandia Test Site.

Building 865 (Advanced Test Accelerator)

The Building 865 area contains the Advanced Test Accelerator, a linear electron accelerator used for charged particle beam research, and control and support buildings. Freon-113 has been detected in groundwater monitor wells located downgradient from a former waste Freon-113 storage tank near the Building 865A machine shop. In 1988, the waste tank was removed and the use of Freon-113 was discontinued. Further characterization will be conducted at Building 865 to determine the nature and extent of contamination.

Building 812 Firing Table

The Building 812 firing table is used for explosives testing. Uranium-238 has been detected at activities up to 22,630 picocuries per liter in soil at a depth of 5 feet beneath the Building 812 firing table. Low activities of uranium-238 have been detected in groundwater collected from two cross-gradient wells near Building 812. Data are inadequate to confirm if contaminant releases have occurred in deeper soil/rock beneath the Building 812 firing table. Further characterization of the Building 812 firing table area is planned.

Sandia Test Site

SNL/CA operated a small, temporary firing table at Site 300 from about 1959 to 1960. The facility consisted of a portable steel building and six other smaller structures, surrounded by sandbags. The buildings and six structures, which are no longer present, may have been either high explosive test chambers or magazines used for storing high explosive materials. Shattered electronic components and structure remnants are still present on the ridge crest to the east and may represent the location of the firing table. Data are inadequate to confirm if contaminant releases have occurred at the Sandia Test Site. Further characterization of this area is planned.

4.17.2.3 *Remedial Actions*

Status of Remediation Efforts

Since 1992, dedicated groundwater and SVE and treatment facilities began operating at the eastern GSA, central GSA, and Building 834 areas. In 2002, eight portable treatment facilities also were operating. Thus, 11 treatment facilities that remove and treat VOCs operated throughout 2002. Twenty-one wells that extract only groundwater, 7 wells that extract only soil vapor, and 24 wells that extract both groundwater and soil vapor operated during 2002, treating 93.1 million liters of groundwater. The 24 wells that extract both vapor and groundwater and the 7 wells that extract only vapor removed 795,960 cubic meters of vapor. In 2002, the Site 300 groundwater and soil vapor treatment facilities removed 9.49 kilograms of VOCs. Since remediation efforts began in 1990, more than 865 million liters of groundwater and 3.93 million cubic meters of vapor have been treated, removing about 231 kilograms of VOCs. Table 4.17.2.2–1 summarizes CY2002 and cumulative totals of volumes and masses of contaminants removed from groundwater and soil vapor at Site 300.

The central GSA, eastern GSA, and two Building 830 treatment facilities discharge to surface drainage courses. Three treatment systems discharge to an infiltration trench. The other four treatment systems discharge to air by misting.

General Services Area

During 2002, the soil vapor extraction and treatment system in the central GSA dry-well source area was continuously operated and maintained to reduce VOC concentrations in soil vapors, remediate dense nonaqueous-phase liquids in the soil, and mitigate the VOC inhalation risk inside Building 875. The groundwater extraction and treatment systems in the central and eastern GSA areas were continuously operated and maintained to reduce VOC concentrations in the groundwater to MCLs, prevent further migration of the contaminant plume, and dewater the shallow water-bearing zone in the Building 875 dry-well area to enhance soil vapor extraction.

At the end of 2002, three wells were being considered for modification as extraction wells for the second phase of planned expansion to the groundwater extraction and treatment facility at central GSA. The addition of these extraction wells would enhance the system’s ability to capture the contaminant plume and increase the mass removal. Treatability tests were being scheduled to determine if passive venting of soil vapor extraction wells in the central GSA area would result in a suitable long-term remedial technology.

Groundwater treated at the eastern GSA groundwater treatment facility was discharged offsite to Corral Hollow Creek, in accordance with the waste discharge requirements order. The central GSA groundwater treatment system is operating under substantive requirements for wastewater discharge issued by the Central Valley RWQCB. Both the central and eastern GSA treatment systems operated in compliance with regulatory requirements during 2002. LLNL submitted quarterly reports for the GSA treatment systems to the California EPA and the Central Valley RWQCB in accordance with the waste discharge requirements order for the eastern GSA and the substantive requirements for waste discharge for the central GSA.

Building 834 Complex

At the end of 2002, groundwater and SVE treatment, using air sparging and granular-activated carbon, respectively, were in progress. Work was initiated during 2002 to expand the well field to wells outside of the core area. Testing the use of aqueous phase granular activated carbon for VOC removal from the groundwater continued during 2002. Plans were being made for the replacement of the current air-sparging system with aqueous-phase granular-activated carbon.

In 2002, the groundwater and SVE treatment systems were operated at full scale for the first half of the year. Equipment problems, followed by programmatic activities, prevented any facility operations for the remainder of the year. The Defense Technologies Evaluations Program began conducting experiments in October 2002. These experiments continued into 2003 and will likely affect future operations. LLNL had been observing a significant drop in both groundwater and soil vapor VOC concentrations in the Building 834 area over the last couple of years. These declining VOC concentrations and temporary suspension of treatment operation provided an opportune time to allow for rebound of contaminants. LLNL plans to conduct detailed monitoring activities following completion of the Defense Technologies Evaluations Program experiments to evaluate potential contaminant rebound in both the vapor and aqueous phase. In situ biodegradation, via reductive dechlorination of TCE, occurs in areas within the Building 834 core area where sufficient amounts of silicon oils exist. However, it was demonstrated that this intrinsic microbial degradation is inhibited during periods of active soil vapor extraction because the soil vapor extraction system draws oxygen-rich vapors into the subsurface and the microbes become dormant. In essence, the SVE system acts like an on/off switch to control biodegradation. As such, allowing the system to remain off-line will promote biodegradation and will achieve some level of mass removal, although this mass is not easily quantified.

During 2001, the combined groundwater and soil vapor VOC mass removal at Building 834 was 31.96 kilograms. During 2002, the combined VOC mass removal at Building 834 was 6.0 kilograms. Table 4.17.2.2–1 shows the volumes of water and soil vapor treated and masses of VOCs removed at Building 834. Quarterly reports for the Building 834 treatment facility were submitted to the EPA, California EPA, and the Central Valley RWQCB in accordance with the substantive requirements for waste discharge. Because treated groundwater is discharged to misters and is not discharged to the ground, there are no treatment system surface discharge permit requirements for Building 834.

TABLE 4.17.2.3–1.—*General Services Area Groundwater Treatment System Surface Discharge Permit Requirements*

Parameter	Treatment Facility	
	Central General Services Area	Eastern General Services Area
VOCs	Halogenated and aromatic VOCs	Halogenated VOCs
Maximum daily	5.0 µg/L	5.0 µg/L
Monthly median	0.5 µg/L	0.5 µg/L
Dissolved oxygen	Discharges shall not cause the concentrations of dissolved oxygen in the surface water drainage course to fall below 5.0 mg/L	Discharges shall not cause the concentrations of dissolved oxygen in the surface water drainage course to fall below 5.0 mg/L
pH (pH units)	Between 6.5 and 8.5, no receiving water alteration greater than ±0.5 units	Between 6.5 and 8.5, no receiving water alteration greater than ±0.5 units
Temperature	No alteration of ambient receiving water conditions more than 3°C	No alteration of ambient receiving water conditions more than 3°C
Place of discharge	To groundwater during dry weather and to surface water drainage course in eastern GSA canyon during wet weather	Corral Hollow Creek
Flow rate	272,500 L/day (30-day average daily dry weather maximum discharge limit)	272,500 L/day
Mineralization	Mineralization must be controlled to no more than a reasonable increment	Mineralization must be controlled to no more than a reasonable increment
Methods and detection limits for VOCs	EPA Method 601—detection limit of 0.5 µg/L EPA Method 602—method detection limit of 0.3 µg/L	EPA Method 601—detection limit of 0.5 µg/L

Source: LLNL 2003l.
°C = degrees Celsius; EPA = U.S. Environmental Protection Agency; GSA = General Services Area; L = liter; µg/L = micrograms per liter; VOC = volatile organic compound.

High Explosives Process Area

In 2002, Phase 3 of the High Explosives Process Area remedial strategy was implemented with the installation of two more extraction wells near the center of mass of the TCE plume. With the addition of these wells, five groundwater extraction wells are in the high explosives process area and the total extraction flow rate is about 30 liters per minute.

To date, more than 10 million liters of groundwater have been extracted and treated by the three existing facilities in the high explosives process area. As presented in Table 4.17.2.2–1, 4.5 million liters of groundwater were extracted and treated during 2002. In addition to removal of 0.027 kilogram of VOCs, 0.134 kilogram of RDX, 0.034 kilogram of perchlorate have also been removed from extracted groundwater. Quarterly reports for the high explosives process area treatment facilities were submitted to the EPA, California EPA, and the Central Valley RWQCB in accordance with the substantive requirements for waste discharge.

Building 854 Area

During 2002, LLNL continued to define the extent of TCE in groundwater and the conceptual hydrogeological model. Three new monitoring wells were installed within the central portion of the groundwater TCE plume.

During 2002, 3.67 million liters of groundwater were treated and discharged at the two treatment systems (Table 4.17.2.2–1). A mass of 780 grams of VOCs, primarily TCE, was removed from this groundwater. The Building 854 Operable Unit discharges were in accordance with the draft Central Valley RWQCB substantive requirements for the Building 832 canyon and Building 854 OUs.

Building 832 Canyon

Table 4.17.2.2–1 shows the volume of water treated and the mass of VOCs removed in the treatment systems during 2002. The Building 854 OU discharges were in accordance with the draft Central Valley RWQCB substantive requirements for the Building 832 canyon and Building 854 Operable Units. Progress of the pump-and-treat systems and groundwater monitoring results are published quarterly.

Building 850/Pits 3 and 5 Operable Unit

At the end of 2002, a remedial investigation/feasibility study was in process for the Pits 3 and 5 area. The anticipated remedial technologies to be implemented at the landfill site include source isolation to prevent further release of tritium and uranium to groundwater. These technologies may include an upgradient groundwater interceptor trench and surface and shallow subsurface water diversion. LLNL is testing reactive media, such as cow bone char and fish bones (apatite mineral sources) and other novel sorbents, for possible deployment in a permeable reactive barrier for removal of depleted uranium from groundwater downgradient Pits of 5 and 7.

Although tritium continues to leach into groundwater from vadose zone sources at Building 850, the long-term trend in total groundwater tritium activity in this portion of the tritium plume is one of decreasing activity at approximately the radioactive decay rate of tritium. The extent of the 20,000 picocuries per liter-MCL contour for this portion of the plume is shrinking.

Nitrate and perchlorate in the Building 850/Pits 3 and 5 area occurred at maximum concentrations of 86 milligrams per liter and 44 micrograms per liter, respectively, in 2002. Trace amounts of TCE (less than 6.4 micrograms per liter) are also present in groundwater near Pit 5.

To determine the appropriate remediation strategy for the Pits 3 and 5 landfills, LLNL is completing a water budget for the Pits 3 and 5 valley, continuing to build and calibrate a three-dimensional geological structural model and model of groundwater flow and contaminant transport, and evaluating several remediation strategies to keep water from entering the landfills. These techniques include subsurface groundwater interceptor trenches, shallow terraced drains, horizontal dewatering wells, landfill grouting, other forms of permeability reduction, and in situ geochemical techniques using sorbents, such as bone apatite, to immobilize uranium in groundwater.

LLNL is also conducting field studies to determine how water recharges the perched water-bearing zone and enters the landfills. These studies include monitoring of wells completed at shallow depths, horizontal wells, and terraced drains, all completed in the hillslope west of the landfills where much of the recharge that enters the landfills originates. Additionally, LLNL is conducting laboratory treatability tests of cow bone char and fish bone in removing uranium from Pits 3 and 5 groundwater. Cow bone char mixed with inert sand has been emplaced in a portion of the alluvial aquifer containing uranium at Pit 5 to test the in situ removal of uranium from area groundwater. Wells within and downgradient of this emplacement are being monitored to define the long-term chemical effectiveness and hydraulic characteristics of the emplaced material. If successful, this emplacement may be expanded as a long-term remedy for depleted uranium in groundwater.

Proposed Remedial Actions

In 1992, a CERCLA federal facility agreement formalized the cleanup process for Site 300 remedial actions. LLNL and NNSA believe that the following proposed major milestones would best meet the criteria established in the agreement (EPA 1992a), the Interim Site-wide ROD for LLNL Site 300 (LLNL 2001u), and the most recent five-year reviews:

FY2004

- Prepare the Building 854 Draft Final Interim Remedial Design Report
- Prepare the Building 854 Final Interim Remedial Design Report
- Prepare the Building 850 Draft Interim Remedial Design Report
- Prepare the Draft Remedial Investigation/Feasibility Study for the Pit 7 Complex
- Conduct a public workshop for the Pit 7 Complex Draft Remedial Investigation/Feasibility Study
- Prepare the Building 850 Draft Final Interim Remedial Design Report
- Prepare the Building 850 Final Interim Remedial Design Report
- Prepare the Draft Final Remedial Investigation/Feasibility Study for the Pit 7 Complex
- Prepare the Final Remedial Investigation/Feasibility Study for the Pit 7 Complex
- Prepare the Building 812 Characterization Summary Report
- Install monitor wells for Building 865 (Advanced Test Accelerator)
- Construct the Building 832-PRX groundwater extraction and treatment facility in the Building 832 Canyon Operable Unit

FY2005

- Prepare the Draft Proposed Plan for the Pit 7 Complex
- Prepare the Building 832 Canyon Draft Interim Remedial Design Report
- Prepare the Draft Final Proposed Plan for the Pit 7 Complex
- Prepare the Final Proposed Plan for the Pit 7 Complex
- Conduct a public meeting for the proposed plan for the Pit 7 Complex
- Prepare the Site-wide Draft Remediation Evaluation Summary Report
- Conduct a public workshop for the Site-wide Draft Remediation Evaluation Summary Report
- Prepare the Draft Amendment to the Interim Site-wide ROD for the Pit 7 Complex
- Prepare the Building 832 Canyon Draft Final Interim Remedial Design Report
- Remove contaminated surface soil at Building 850
- Remove the contaminated sand pile at Building 850
- Prepare the Building 832 Canyon Final Interim Remedial Design Report
- Prepare the Building 865 (Advanced Test Accelerator) Characterization Summary Report
- Conduct surface soil sampling for the Sandia Test Site
- Construct the Building 829-SRC groundwater extraction and treatment facility in the High Explosives Process Area Operable Unit
- Construct the Building 817-PRX groundwater extraction and treatment facility in the High Explosives Process Area Operable Unit

FY2006

- Prepare the Site-wide Draft Final Remediation Evaluation Summary Report
- Prepare the Site-wide Final Remedial Evaluation Summary Report
- Prepare the Draft Final Amendment to the Interim Site-wide ROD for the Pit 7 Complex
- Prepare the Site-wide Draft Proposed Plan for the Final ROD
- Prepare the Final Amendment to the Interim Site-wide ROD for the Pit 7 Complex

- Conduct a public workshop for the Site-wide Draft Proposed Plan
- Prepare the GSA Draft Five-Year Review
- Prepare the Site-wide Draft Final Proposed Plan for the Final ROD
- Prepare the Site-wide Final Proposed Plan for the Final ROD
- Prepare the Pit 7 Complex Draft Interim Remedial Design Report
- Conduct a public meeting for the Site-wide Draft Proposed Plan
- Prepare the GSA Draft Final Five-Year Review
- Prepare the Building 834 Draft Five-Year Review
- Prepare the GSA Final Five-Year Review
- Hook up the Building 830-PRX extraction wells to the Building 830-SRC groundwater treatment system in the Building 832 Canyon Operable Unit
- Construct the Building 830-DIS groundwater extraction and treatment facility in the Building 832 Canyon Operable Unit
- Prepare the Sandia Test Site Characterization Summary Report

FY2007

- Prepare the Site-wide Draft ROD
- Prepare the Pit 7 Complex Draft Final Interim Remedial Design Report
- Prepare the Pit 7 Complex Final Interim Remedial Design Report
- Prepare the Building 834 Draft Final Five-Year Review
- Conduct a public workshop for the Site-wide ROD
- Prepare the Building 834 Final Five-Year Review
- Prepare the Site-wide Draft Final ROD
- Prepare the Site-wide Final ROD
- Prepare the Site-wide Draft Revised Remedial Design Work Plan
- Expand the Building 817-PRX groundwater extraction and treatment facility in the former high explosive lagoon area

- Construct the Building 832-DIS groundwater extraction and treatment facility in the Building 832 Canyon Operable Unit

FY2008

- Prepare the Site-wide Draft Final Revised Remedial Design Work Plan
- Prepare the Site-wide Final Revised Remedial Design Work Plan
- Prepare the Site-wide Draft Revised Compliance Monitoring Plan/Contingency Plan for Final Remedies
- Prepare the Site-wide Draft Final Revised Compliance Monitoring Plan/Contingency Plan
- Prepare the Site-wide Final Revised Compliance Monitoring Plan/Contingency Plan
- Install enhanced monitoring systems at the Pit 2, Pit 8, and Pit 9 landfills

Consistent with the agreement, the final selected remedies and cleanup standards will not be determined until the issuance of the Site 300 final ROD, scheduled for 2007. The interim ROD covers additional testing and evaluation of technologies, proposed final cleanup standards, and proposed investigations. NNSA expects GWTSs and other remedial actions to be in place and operational by 2009. NNSA will continue to operate treatment systems until cleanup levels are achieved and to manage remedial sites as part of the site-wide long-term stewardship effort.

4.17.3 Environmental Impacts of Contamination

In the 1992 LLNL EIS/EIR, environmental impacts resulting from a no-remediation scenario were presented. For this LLNL SW/SPEIS, a no-remediation scenario is also presented.

The extent of groundwater and soil contamination at the Livermore Site and Site 300 is discussed earlier in this section. Cleanup and remediation are required by law and LLNL is fully committed to these efforts; however, for purposes of a complete analysis of the existing setting, this section discusses the environmental effects on the existing environment assuming there is no remediation.

Over the last 10 years, LLNL, with Federal and state approval, has been actively remediating known areas of contamination. If no remediation of groundwater or soils were to occur, environmental impacts could result, as summarized below.

4.17.3.1 *Livermore Site*

In 1991, as part of the evaluation of remedial alternatives for groundwater and soil cleanup at the Livermore Site conducted under the Federal Facility Agreement (FFA), a no-remediation alternative was evaluated to provide a baseline from which to evaluate the various remedial alternatives. As remedial alternatives were implemented, as would be expected, remediation efforts have reduced the extent and concentration of contaminants in the environment.

Based on 2002 information, potential environmental impacts that could occur as a result of the no-remediation scenario are summarized as follows:

- Exceedance of regulatory agency-approved levels would place DOE in a situation of noncompliance with state and Federal laws.

- Contaminants in the unsaturated zone could migrate to groundwater in some areas of the Livermore Site.

- Concentrations of contaminants in groundwater would exceed state and Federal regulatory levels over broader areas.

- Degradation of the Livermore area groundwater would occur over a larger area as contamination plumes resume migration. The contaminant plumes would again migrate downgradient toward local water supply wells and city of Livermore municipal wells. This could inhibit future beneficial uses of increasingly greater proportions of the aquifer system. Over time, however, reduction in chemical concentrations would occur through natural attenuation processes, including biodegradation, dispersion, and abiotic degradation.

Twelve active domestic drinking water supply wells and seven industrial and/or agricultural supply wells are located within 1 mile of the Livermore Site VOC groundwater plumes (Hong 2002). These wells are generally either transverse, cross gradient or upgradient, or are in a different groundwater regime; therefore, they do not appear to be in the direct (downgradient) flow path of the plumes. Should lateral dispersal be significant or should a change in groundwater flow direction occur (which are both highly unlikely scenarios based on existing data), these wells could be affected by the advancing plumes. Additionally, although further development of the groundwater resource in the vicinity of the VOC plumes for domestic consumption is unlikely, development of additional water sources for irrigation is highly possible.

Groundwater data gathered in the remedial efforts indicate that impacts from VOCs in groundwater have stabilized and are declining (LLNL 2003l). If remediation were to cease and if contaminated groundwater were to reach municipal wells, economic impacts associated with the loss of water resources to local water consumers could result. Water purveyors supplying water pumped from municipal wells to constituents would need to treat the contaminated water sources or purchase water from other sources, resulting in increased water costs. Given the estimated maximum concentrations of TCE (6 parts per billion) and perchloroethene (5 parts per billion) would occur after 950 years (the MCLs of both these VOCs are 5 parts per billion), the impact would be minimal (Toblin 2003). This is a conservative estimate in that no degradation is assumed.

Assuming that no remediation occurs and contamination reaches municipal wells and that an individual consumes 2 liters of water each day from a municipal well in downtown Livermore for a 70-year (lifetime) period, the maximum additional cancer risk from a lifetime exposure to VOCs (TCE and perchloroethene are assumed to be the VOCs for the purpose of health estimates) could be 2×10^{-6} (Toblin 2003). This risk is much lower than the normal 1 in 4 cancer risk faced by all Americans due to both natural and artificial (i.e., medical) radiation exposures.

Assuming that an individual consumes 2 liters of water each day from a hypothetical drinking water well located 250 feet west of the Livermore Site boundary for a 70-year (lifetime) period, the maximum additional cancer risk from exposure to these same constituents would be 8×10^{-6}, based on present concentrations (~50 parts per billion of VOCs). However, administrative controls discouraging the use of this water for drinking and the continued availability of municipal water would greatly reduce, if not eliminate, this possibility.

Under the no-remediation scenario, tritium could migrate through soils to groundwater and be transported by groundwater. By the time the tritium reached the Livermore Site boundary, however, the tritium would have naturally decayed to lower concentrations.

Chromium in groundwater would again migrate downgradient and offsite. However, the levels of chromium are so low that combined with further dilution and natural attenuation, chromium would not likely represent an offsite health threat.

4.17.3.2 *Site 300*

Environmental investigations and cleanup activities at Site 300 began in 1981. Site 300 became a CERCLA site in 1990, when it was placed on the NPL. At present, eight CERCLA environmental restoration Operable Units are being managed to mitigate contamination at Site 300. These Operable Units are the GSA; Building 834 Complex; High Explosives Process Area; Building 850/Pits 3 and 5; Building 854, Pit 6; Building 832 Canyon, and other areas at Site 300. Details of the extent of contamination and proposed remedial action strategies are presented in Section 4.17.3, Site Contamination—Site 300.

Based on 2002 information, environmental impacts that could occur as a result of the no-remediation scenario are summarized as follows:

- Exceedance of regulatory agency-approved levels would place DOE in a situation of noncompliance with state and Federal laws.
- Contaminants in unsaturated zone soil could migrate to groundwater in many of the Operable Units.
- Concentrations of contaminants in groundwater and soil could again exceed state and Federal regulatory levels.
- Degradation of Site 300 groundwater over a larger area could occur as the plumes resume migration. The VOC and other contaminant plumes would migrate downgradient toward the site boundaries.

Groundwater data gathered in the remedial efforts indicate that impacts have stabilized and are declining (LLNL 2003l). If the no-remediation scenario were to occur, this trend would reverse.